Bozeman Creek Enhancement Project

at Bogert Park

Preliminary Design Report

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Introduction

Originating in the Gallatin Mountains, Bozeman Creek flows north through the Gallatin Valley before running through the heart of Bozeman, Montana. The creek is one of the largest tributaries to the East Gallatin River and provides an excellent enhancement and restoration opportunity within an urban setting.

Historic manipulations of Bozeman Creek, particularly near downtown, have reduced the once meandering channel into a straightened ditch with several culverts and pipes conveying the stream beneath streets and parking lots. Much of the ecological value of the creek has been lost as the riparian and floodplain corridors have largely been developed. In-stream habitat has also been severely compromised by the simplification of the channel into a nearly straight alignment throughout most of its length within the city limit.

The Bozeman Creek Enhancement Committee (BCEC) formed to identify community-supported actions that could be taken to improve water quality, habitat, recreation and access, and other aspects of the creek corridor. The group is headed by a working group of community organizations and individuals, in collaboration with the Bozeman Parks Division and the National Park Service's Rivers & Trails Program. A creek enhancement project at Bogert Park was identified as a high-priority by the BCEC due to the site's primary ownership by the city, high visibility and proximity to the center of town, strong public support, and value as a demonstration project. Enhancement of Bozeman Creek at Bogert Park will assist in attaining the goals of the Bozeman Creek Enhancement Project including:

- Improve Bozeman Creek channel, floodplain, and riparian structure and function
- Enhance habitat for fish and wildlife
- Minimize non-point source pollution of surface and ground water from sediment, biological pathogens, excess nutrients, urban pollutants and hazardous wastes
- Provide additional open space, greenways, and public parks along the creek
- Construct new trails that integrate the creek corridor into community life, while improving connectivity within the "Main Street to the Mountains" trail system
- Foster a recreational fishery emphasizing opportunities for kids as aquatic habitat and water quality improve
- Provide or improve desirable amenities at existing and new creekside parks
- Inform residents about the natural resource values of the creek corridor, the ecological services it provides, its past and present importance to the Bozeman community, and the work of the BCEC.

The BCEC performed an alternative analysis with substantive public involvement for improving Bozeman Creek through Bogert Park in 2011. The preferred alternative included creating meanders and an inset floodplain to re-establish a more naturally functioning and safer stream channel that provides a more significant and appreciated amenity to park users. Preliminary surveys indicated an opportunity to create two full meander bends through the park and adjusting park infrastructure to complement the creek. Design figures produced for this alternatives analysis are included in Appendix A of this report.

The City of Bozeman contracted Confluence Consulting, TD&H Engineering, Design 5, Intrinsik Architecture, Inc. and Nishkian Monks to prepare preliminary plans for enhancing Bozeman Creek through Bogert Park based on the selected alternative. Preliminary designs include plans for routing the creek through two new meanders, constructing an inset floodplain, revegetation of the riparian corridor, altering the park's playground and trail system, creating an improved creek access area, moving existing utilities as necessary to accommodate the stream enhancement, and replacing the existing bridge spanning Bozeman Creek. This report describes and illustrates each of these park enhancement components in further detail. Design drawings are included in Attachment 1.

Preliminary Design Components

The preliminary design for Bozeman Creek includes altering the stream channel alignment and adjusting the park's playground, trails, footbridge, and utilities to complement the creek. Primary design components include:

Bozeman Creek Stream Channel

- Realignment of Bozeman Creek including two meander bends to allow for additional habitat complexity,
- Creating an inset floodplain for Bozeman Creek to provide additional flood capacity,
- Increasing habitat diversity by creating pool and riffle complexes,
- Enhancing the riparian corridor along Bozeman Creek through the park.

Bogert Park Infrastructure

- Replacing the existing pedestrian bridge spanning Bozeman Creek from Koch Street,
- Altering the existing park trail system to better accommodate the new bridge alignment, traffic patterns, and allow for mixed use of pedestrians and bikers,
- Altering the playground layout to accommodate a new stream alignment, stream access areas, and revised trail system,
- Improving recreational access to the stream in specified areas while discouraging access in other areas,
- Moving power and irrigation lines to accommodate a new stream alignment,

This design report is accompanied by a set of design sheets (Attachment 1) illustrating details for each of these primary design components. A master plan for the enhancement of Bozeman Creek in Bogert Park illustrating the channel alignment and revised trails and bridge is shown on Sheet 2 of the drawing set. The following narrative sections provide details of the proposed approaches, analyses performed, and design criteria established for each component of the Bozeman Creek Enhancement Project.

Bozeman Creek Stream Channel

The overall vision for enhancing Bozeman Creek through the park involves altering the alignment of the channel, expanding floodplain capacity, and establishing a vegetated riparian corridor adjacent to the channel. This requires an analysis of several factors to ensure the newly constructed channel segment will provide ecological and recreational benefits over the long term. The following analyses were performed and design criteria established as part of the preliminary design process for Bozeman Creek:

Hydrology

Bozeman Creek has almost no available gage data records available to assist in predicting typical flood discharges. A USGS gage installed in Sourdough Canyon recorded flows from May 1, 1951 to September 30, 1953, but does not provide sufficient data to predict peak flows. The USGS recommends a minimum of 10 years of data for a flood frequency analysis. Lacking gage data specific to Bozeman Creek, regional regression equations developed by the USGS (Johnson and Parrett 2004) are an acceptable hydrologic analysis method as long as the basin characteristics of the project site are within the range used to derive the equations. Bozeman Creek is located in the Upper Yellowstone-Upper Mountain hydrologic region. For this region, regression equations factor drainage area and the percentage of the drainage area above 6,000 feet elevation. The range of values used to develop the regression equations are 0.47-2,032 square miles for drainage area and 0-100% for percentage of the drainage area above 6,000 feet elevation. With 63.1% of the 51.6 square miles drainage area above 6,000 feet, Bozeman Creek at Bogert Park falls within the acceptable range of values for the regional regression equations.

Table 1 provides discharges at various return intervals for Bozeman Creek at Bogert Park as calculated with the regression equations. The drainage areas were delineated using USGS 12 code hydrologic units and USGS topographic maps in ArcGIS.

Table 1. Results of USGS regression equations for Bozeman Creek at Bogert Park.

Bozeman Creek at Bogert Park									
Upper Yellowstone Region Drainage Area >6000’ = 32.6 sq. mi (63.1%) Drainage Area <6000’ = 19 sq. mi (36.9%) Total Drainage Area = 51.6 sq. mi	Return Interval (yr)	2	5	10	25	50	100	200	500
	Q (cfs)	233	419	574	803	994	1198	1414	1732

An independent hydrologic analysis was also performed by Allied Engineering to develop a hydraulic model of Bozeman Creek through downtown Bozeman (Appendix B). A draft of this report dated March 2, 2012 described a methodology for predicting a surrogate bankfull flow for Bozeman Creek through downtown Bozeman under pre-disturbance conditions. The surrogate bankfull flow in that report was derived using data from three other gaged streams in the Gallatin Valley, an estimate of the natural slope of Bozeman Creek prior to it being channelized, and channel widths measured from LiDAR data and high resolution aerial photos upstream of the city limits. See Appendix B for a full description of the methods used. The authors reasoned that pre-disturbance flows were reasonably similar to present-day, post-disturbance flows based on the limited influence of urban stormwater runoff in the snowmelt-driven hydrology of Bozeman Creek at low probability peak flows such as the 100-year discharge. The method Allied used may slightly underestimate bankfull flows at Bogert Park, as the estimated flow of 208 cfs was partially based on an analysis of existing bankfull channel widths 3.5-4.5 miles upstream. However, prior to factoring in the existing channel widths, the Allied report estimated a natural bankfull width of 28 feet through downtown Bozeman.

To more accurately determine the extent, dimensions, and bankfull discharge of the existing channel through the park, we surveyed five cross-sections through Bozeman Creek between Story St. and Olive St. An at-a-station hydraulic program (WinXSPro) was used to determine the stage, cross-sectional area, and top-width of the existing channel at various discharges. The average channel width in Bogert Park during a 2-year discharge of 233 cfs (as estimated by regional regression equations) was 28.5 feet, which closely corresponded to the estimated bankfull width reported by Allied prior to factoring in existing channel widths upstream of the project site. All WinXSPro hydraulic modeling results are included in Appendix C of this report.

A bankfull design discharge of 233 cfs was selected for preliminary design based on our review of the hydrologic analysis performed by Allied Engineering, the at-a-station hydraulic modeling of surveyed cross sections, the regional regression equations, and best professional judgment. This discharge is the 2-year return interval flow as predicted by regional regression equations, but does not necessarily correspond to a naturally occurring bankfull discharge. Most snowmelt driven streams exhibit bankfull discharges that fall between a 1 and 2-year return interval (Knighton 1998). The bankfull design discharge of 233 cfs was used to determine the dimensions of the proposed bankfull channel and the corresponding elevation of the proposed inset floodplain.

Base Flows in Bozeman Creek

A discharge measurement was taken at the north end of Bogert Park to estimate base flow on April 2nd, 2012 using a Marsh-McBirney flow meter. Rain the previous day had caused an increase in flow, and a discharge of 53.5 cfs was measured (Appendix D). Gage data for the East Gallatin River (USGS gage #06048700) on April 2, 2012 were used to adjust the measured discharge on Bozeman Creek and derive an estimated base flow. The discharge in the East Gallatin River was 152 cfs on April 2nd. Average base flow discharge (defined as the average of daily mean flows in December, January, and February) in the East Gallatin River was 44 cfs. Base flow in the East Gallatin River was 71% lower than the gage discharge of 152 cfs measured on April 2nd. This factor (71%) was used to adjust the April 2 discharge measured on Bozeman Creek to derive an estimated base flow of 15.5 cfs.

Additionally, the gage data for USGS #06047500 on Bozeman Creek near Bozeman were used to verify the base flow estimate. The gage was in operation from May 1, 1951 through September 30, 1953, and the average daily mean flow for December, January, and February was 8.7 cfs.

Finally, Allied Engineering developed a mean daily hydrograph for Bozeman Creek based on a synthesis of three gages: Rocky Creek, Bear Canyon, and Bridger Creek. Mean daily flows from the three gages were pro-rated based on a drainage area ratio. Average base flows were estimated to be 10 cfs.

Based on these three methods, the base flow in Bozeman Creek is estimated to be between 8 and 16 cfs and occurs during mid-winter.

Channel Alignment

Bozeman Creek is currently channelized for approximately 800 feet through Bogert Park and has been largely armored along the left (west) bank with rock, concrete, and debris. The Bozeman Creek Enhancement Committee performed an alternatives analysis with substantive public involvement for improving Bozeman Creek through Bogert Park. The preferred alternative included establishing meanders to provide a more naturally functioning stream channel that also provides a more significant amenity to the park. Several constraints including residential property boundaries and infrastructure (band shell, pavilion, irrigation, utilities, large trees, and playground) limited opportunities for re-establishing a naturally meandering channel through the park.

The proposed channel alignment and resulting channel profile are illustrated on Design Sheet 3 (Attachment 1). This alignment complies with design criteria identified through the conceptual planning process, including:

1. Meander bends will be designed to allow the existing municipal sewer line to remain undisturbed.
2. Meander bends must be designed to minimize removal of existing trees, except where specific trees have been identified as decadent or otherwise expendable by the Bozeman Parks Department.
3. Channel alignment will maximize opportunity for channel enhancement and habitat diversity associated with meander bends, while maintaining all other design criteria.

Channel Dimensions

All natural stream channels exhibit variability in width and depth as sediment erodes and deposits within the channel and floodplain. Incorporating variability in stream channel designs creates a more naturally appearing and aesthetically appealing project. In addition, variability increases habitat complexity in the form of riffles, pools, variable flow velocities, and substrate sizes. Each of these habitat variables contributes to the biological integrity and diversity of fish and other aquatic life. Habitat diversity was incorporated into the design of Bozeman Creek by including variable channel widths and two meander sequences, which include riffle and pool components.

For the purposes of preliminary design, a bankfull channel template was derived by surveying five cross sections of the existing channel, then running an at-a-station hydraulic model at each cross section, and determining channel dimensions at a discharge of 233 cfs. This analysis was essentially a reference reach approach that used the existing channel as an internal reference. Although the existing channel had been heavily manipulated, it was stable both vertically and laterally and was suitable for developing preliminary design dimensions for the relocated channel segment, including bankfull width, maximum depth, mean depth, and width/depth ratio.

Table 2. Cross section dimensions of five surveyed cross sections in Bozeman Creek at Bogert Park @ 233 cfs.

Cross Section	Max Depth (ft)	Cross Section Area (sq ft)	Top Width (ft)	Mean Depth (ft)	Width/Depth Ratio
1	2.52	38.2	21.88	1.75	12.50
2	2.19	45.64	34.9	1.31	26.64
3	2.01	44.05	31.93	1.38	23.14
4	2.36	42.52	29.09	1.46	19.92
5	2.23	39.97	24.75	1.61	15.37
Average	**2.26**	**42.08**	**28.51**	**1.50**	**19.52**

Riffle Design

Surveys of the five cross sections in the existing channel indicated an average top width of 28.5 feet, average mean depth of 1.5 feet, and average width/depth ratio of 19.5 at a discharge of 233 cfs. These cross-sections were all located within riffle habitat, so the average surveyed dimensions were prescribed as the average design dimensions for riffles within the relocated channel segment (Table 3).

Variability in Riffle Dimensions

To incorporate variability into riffle dimensions, the average channel top width (or bankfull width) of 28.5'was adjusted by +/- 10% to derive minimum and maximum channel width values. Minimum and maximum width cross-sections were then re-run through at-a-station hydraulic software (WinXSPro) to determine the channel depth at 233 cfs (Results in Appendix C). Mean bankfull depth, maximum bankfull depth, and width/depth ratios for the minimum-width and maximum-width channel cross section were calculated and are included in Table 3.

Pool Design

Preliminary design of pool habitat in the relocated channel segment was based an analysis of scour depth, target width/depth ratios, and professional judgment. In meandering stream channels, pool dimensions are typically narrower and deeper than riffles and consequently exhibit lower width/depth ratios. The average bankfull width of pools was determined by setting the average bankfull pool width equal to the minimum riffle depth (25 feet). Pool depths were estimated by running scour calculations at 233 cfs through a channel cross section with top width of 25 feet and mean particle size of 20 mm (0.8"). The scour analyses estimated a pool depth of 1.3 feet below the bed elevation at bankfull flows (Results in Appendix E). The resulting pool depths for the average, minimum, and maximum pool widths are included in Table 3.

Variability in Pool Dimensions

To incorporate variability in pool dimensions, the design top width (bankfull width) of 25' was adjusted by +/- 10% to derive minimum and maximum pool widths. Maximum and mean pool depths were estimated by running scour calculations for the minimum and maximum channel widths at 233 cfs. Table 3 presents the existing channel dimensions and a range of design dimensions for pools within the relocated segment of Bozeman Creek through Bogert Park.

Table 3. Existing and proposed cross section dimensions for relocated segment of Bozeman Creek through Bogert Park.

Chanel Segment	Parameter	Reach Average (ft)	Reach Minimum (ft)	Reach Maximum (ft)
Existing channel	XS Bankfull width	28.5	22	35
	XS Mean bankfull depth	1.5	1.3	1.7
	XS W/D ratio	19.5	12.5	26.6
Riffles in relocated channel segment	XS Bankfull width	28	25	31
	XS Mean bankfull depth	1.5	1.4	1.6
	XS Max bankfull depth	1.75	1.6	1.9
	XS W/D ratio	19	15.2	21.6
Pools in relocated channel segment	XS Bankfull width	25	23	27
	XS Mean bankfull depth	2.1	2.0	2.2
	XS Max bankfull depth	3.2	3.1	3.5
	XS W/D ratio	12.1	13.3	10.7

When the proposed riffle and pool dimensions are combined, channel widths vary between 23 feet and 31 feet (25% variability), while maximum channel depths vary between 1.5 and 3.75 feet (40% variability). Cross section dimensions for riffles and pools within the new meanders are illustrated in Cross Section 1 and 2, respectively on Design Sheet 4 (Attachment 1). Cross Section 3 on Design Sheet 4 illustrates typical dimensions for reaches of the channel where it will remain in its existing alignment.

Specific design criteria for channel dimensions include:

1. Channel dimensions will convey a bankfull discharge.
2. Riffle widths will vary by +/- 10% from the average width.
3. Pool widths will vary by +/- 10% from the average width.
4. Pool depths will vary based on estimated depth of scour at various design widths.

Stream Habitat

The creation of meander bends within the park provides an excellent opportunity for diversifying stream habitat. The existing channel is straight and is considerably more simplified in habitat complexity than a more sinuous and naturally meandering channel. A meander bend sequence typically includes alternating riffle and pool formations that develop as a result of scour and depositional processes. Riffles typically develop along the straight segments of the channel where the flow is laminar and scours the stream bed and banks evenly. Pools typically form along meander bends where the channel scours the outside margin of the stream bed.

New meanders proposed along Bozeman Creek will be designed with bed and bank features suitable for pool and riffle formation (see criteria for bed and stream bank composition) to provide additional habitat complexity for fish, macroinvertebrates, and other aquatic life in the creek. Riffle features should be designed to allow for fish passage during periods of base flows. Literature suggests minimum stream depths for trout passage as low as 0.5" (Cahoon et al 2004); however other studies suggest minimum depths between 3" (Saltzman and Koski 1971) and 6" (Baker and Votapka 1990). Spawning habitat for brown trout should also be provided by designing riffle dimensions to provide suitable depth and velocity as outlined in habitat suitability index models (Raliegh et al 1986). Pool features will provide resting and feeding areas for adult fish. Although minimum pool depths for trout are not well documented, scour calculations predict a minimum bankfull pool depth of approximately 3.2 feet at base flows. Locations of proposed pool habitat features in the new meanders are illustrated on Design Sheet 3 (Attachment 1). Typical cross sections illustrating riffle and pool dimensions and shapes are included on Design Sheet 4.

Specific design criteria for habitat features in Bozeman Creek include:

1. Riffle features will be developed in straight channel segments that transition between meander bends.
2. Riffle features will be designed to a minimum depth of 6" and velocity of approximately 1.5 feet/second at the average discharge during fall spawning season (October – December) to encourage brown trout spawning.
3. Riffle features will be designed to a minimum depth of 4" during base flows (January – February) to allow for fish passage.
4. Pool features will be developed to correspond with- and extend just downstream of- the apex of each meander bend.

Lateral Stability and Bank Treatments

Altering the stream alignment will redirect flows throughout the course of each new meander. The downstream end of each meander will direct flows toward the west bank and privately owned properties along this bank. The upstream end of each meander will direct flows toward the east bank and park infrastructure. Consequently, the new meanders will create additional scour forces along each outside bank (east and west). Various bank treatments are proposed based on the position along the stream, whether the bank is against the park to the east or the private property to the west. Each bank treatment scenario is described in more detail below.

Bank construction along affected reaches on the west side of the channel

The existing west bank of the creek is relatively steep and has well-rooted, mature shrubs and trees growing on the upper banks. Bank armor may be necessary to protect this vegetation and adjacent private property from lateral erosion. A hydraulic scour analysis will be performed during final design to estimate the shear forces exerted along the west bank and evaluate whether the existing bank materials are capable of withstanding that shear. If the existing materials are adequate to resist erosion, the bank will remain in its existing condition. If not, stone toe armor will be installed to protect the bank from eroding. This toe armor, if needed, will be installed to an upper elevation that corresponds to the extent of rooted vegetation along the bank or to the bankfull elevation, whichever is lower; and below the estimated depth of scour. Vegetation along the upper bank will not be disturbed. Installation of toe armor may require the eastern bank of the channel to be moved slightly east to maintain a bankfull discharge capacity. A typical illustration for stabilizing banks in these areas is included in typical cross section details on Design Sheet 4 (Attachment 1). The extent of these toe treatments is shown on Design Sheet 3.

If a stone toe is determined to be necessary to stabilize the west bank, design criteria for these banks will include:

1. The stone toe will be sized to withstand maximum shear at a 100-year flood event at the toe of the banks.
2. The stone toe will be installed with an upper elevation equivalent to the bankfull elevation or the extent of rooted vegetation, whichever is lower.
3. The stone toe will be installed with a lower elevation equivalent to the estimated depth of scour as a factor of safety.

If hydraulic modeling indicates placement of a stone toe is unnecessary, no design criteria for the west banks are proposed.

Bank construction along new channel meanders
Newly constructed channel segments will be at risk of erosion immediately following construction, as they will not have a well-established riparian vegetation corridor to provide natural erosional resistance. Given that the channel flows through private property and a city park, it will need to remain in a relatively static location. As such, the banks of the creek will be designed to retain their shape to the extent possible while allowing for the establishment of a natural riparian corridor. Banks along the outside bends of the channel will be constructed with a cobble material foundation overlaid with biodegradable coir fabric soil lifts. The cobble materials will provide a stable toe for the soil lifts as well as protection against lateral migration. The soil lifts will provide a medium for vegetation on the upper bank. The inside banks of the meanders will be constructed as cobble and gravel point bars. A typical cross section view of this approach is presented in cross section on Design Sheet 4.

A cobble revetment will be buried along the east side of the inset floodplain to prevent lateral erosion of the channel further east into the park. This revetment will use cobble as opposed to angular rock, as it will be much more visually appealing and safer to walk on should the channel migrate laterally against it. The use of rounded cobble requires installing stone approximately 33% larger than angular riprap sized to remain immobile at the 100-year flood event.

Specific design criteria for lateral stability in the new meanders include:

1. Bank materials will be sized to withstand shear at a 25-year discharge.

2. On outside meander bends, the top of the banks will be stabilized with coir fabric capable of withstanding shear forces up to a 25-year flood event.
3. The channel banks will be armored in the vicinity of the footbridge to protect bridge abutments and channel from shear exerted at the toe of the banks at a 100-year discharge.
4. A buried cobble revetment installed along the east side of the channel will resist lateral erosion up to the 100-year flood event.

Vertical Stability and Stream Bed Composition

The Bozeman Creek channel bed is vertically controlled on both the upstream and downstream ends by culverts. The upstream culvert flows underneath Story Street, while the downstream culvert flows underneath Olive Street. These culverts act as grade controls and prevent vertical migration in the stream bed beyond the project reach. In addition, the existing bed within the project reach is stable, showing no signs of recent vertical adjustment. As a result, there is no need to establish additional grade control within the project reach to prevent grade adjustments or head cutting.

Stream bed materials in the existing channel were sampled at three locations using a Wolman pebble count technique. This method requires sampling and classifying 100 particles into size categories based on the diameter of their intermediate axis. Results of this analysis (Appendix F) may be developed into a graph of particle size distribution on a logarithmic scale to determine the mean (D_{50}) particle size. The D_{50} particle size in Bozeman Creek based on conducting three pebble counts at riffles is approximately 20mm (0.7 inches), classified as coarse gravels. This mean particle size was used in scour calculations and as a reference to set the Manning's n roughness coefficient within the channel during HEC-RAS modeling.

Within the new meanders, grade will be maintained by constructing riffles at the straight segments between each meander bend. Riffles will be constructed using cobbles, and will provide habitat for macroinvertebrate production. Pools will also be constructed along the downstream extent of each meander bend, and will be allowed to scour and establish deeper water habitat.

Specific design criteria for stream bed composition include:

1. In new meanders, riffles will be constructed using round cobbles sized to withstand mobility up to the 10-year discharge, as predicted by regression equations.
2. In new meanders, pools will be constructed using a gravel gradation with a D_{50} that will be mobile at the 2-year discharge to encourage deeper water habitat.

Inset Floodplain Development

The existing, channelized configuration of Bozeman Creek has likely resulted in vertical migration of the stream bed downward from its original elevation. Although this vertical migration has not been documented, the likelihood of this process is evident based on the existing channel's capacity to contain the estimated 100-year discharge within its banks. Consequently, this reach of Bozeman Creek is disconnected from its historic floodplain, which likely extended well beyond the channel margins and into areas that are currently residential and park development. Approximate extents of the current 100-year floodplain are shown in FEMA floodplain maps on Design Sheet 5 which indicate flooding will occur along the downstream end of the park in the vicinity of the pavilion. Estimated 100-year flood discharges are contained within the existing channel in the upstream end of the park.

The confinement of flood discharges within the channel prevents natural sediment deposition and overbank flooding processes typical of a naturally functioning stream system. To remedy this impairment, the preliminary design includes constructing an inset floodplain along the project reach to allow discharges >233 cfs to escape the bankfull channel and flow across a broader floodplain area. This inset floodplain will provide areas for sediment deposition and will slow stream velocities in flooded areas (see results of predicted channel velocities in Appendix G).

In areas where the channel meanders, the inset floodplain will include a flat, floodplain bench on the inside of each bend and a narrow, flat floodplain bench on the outside of each meander. In areas where the channel will remain in-place, the inset floodplain will be constructed along the eastern side of the channel, and will include a flat, floodplain bench and a resloped bank to meet the top of the bank in the park. The extent of the inset floodplain adjacent to the pavilion will need to take into account the footers installed to support the pavilion structural arches. The extents of the footers were estimated by probing the soils around three of the footers. The results of soil probing were inconclusive, although a footer on the southwest corner of the pavilion was detected approximately two feet deep and 3-3.5 feet laterally from the exposed concrete arch. Rocky material was found at shallower depths, indicating a potential that the footers were buried with rock underneath a topsoil layer. Excavation in the vicinity of the footers will be required during final design to determine the subsurface extents and to finalize the limits of the inset floodplain.

Design Sheet 3 illustrates the extent of the inset floodplain, while cross sections on Design Sheet 4 provide a typical scenario of inset floodplain development within the project reach.

Specific design criteria for the inset floodplain include:

1. The inset floodplain will be designed at an elevation to allow discharges >233 cfs to escape the bankfull channel and spread across the inset floodplain.
2. In areas where the channel meanders, the inset floodplain materials will include round cobbles capable of withstanding mobility up to a 25-year discharge and will be capped with topsoil or soil lifts to encourage vegetative growth.
3. The inset floodplain will be designed to the extent possible to minimize existing mature tree removal while meeting other design criteria.
4. The eastern bank of the inset floodplain will be sloped at a 5:1 ratio up to the existing elevation of the park wherever possible.
5. The eastern bank of the inset floodplain will be sloped at a ratio steeper than 5:1 in select areas to reduce mature tree removal to the extent possible.

100-year Floodplain through Bogert Park

Hydraulic modeling efforts performed by Allied Engineering through downtown Bozeman provided an “existing conditions” scenario of water surface elevations at various flow return intervals. Approximate extents of the current 100-year floodplain are shown in FEMA floodplain maps on Design Sheet 5 (Attachment 1). The maps indicate that in its present state, minor flooding will occur in Bozeman Creek along the downstream end of the park in the vicinity of the pavilion. Elsewhere within the park, the existing channel fully contains the 100-year discharge.

The hydraulic model was revised to include additional cross-sections and to reflect the proposed average dimensions of the new channel through Bogert Park (“proposed conditions” scenario). The proposed conditions model also includes a new footbridge, meandering channel and inset floodplain (Results in Appendix G). Design Sheet 5 shows the anticipated 100-year flood elevations of the proposed project following construction of the new meanders, inset floodplain, and new bridge. A comparison of existing conditions to proposed conditions indicates an average drop in the 100-year flood water surface elevation by 1.2 feet in areas proposed for new channel meanders and inset floodplain development. However, the expanded floodplain will not contain the estimated 100-year flood event in areas near the pavilion, as shown by the extent of flooding.

It is important to note the hydraulic modeling of proposed conditions was based on preliminary grading plans, which are subject to change during final design. In addition, flood elevations estimated by preliminary hydraulic modeling should not be used for regulatory or permitting purposes.

Specific design criteria for the 100-year floodplain include:

1. The project will not increase the 100-year flood elevation (FEMA FIRM maps, effective 2011) within or upstream of Bogert Park.

Vegetation

Although vegetation will be removed for the stream channel realignment, this will be replaced by a greater amount of native vegetation. The banks of the existing creek are characterized by mature cottonwood trees and shrubs and a sporadic, younger understory. Unrestricted access to the stream adjacent to the pavilion has left the stream banks and riparian vegetation in degraded condition. By managing storm water runoff, restricting stream access, and heavily planting the new stream channel, Bozeman Creek will become a greater asset to the City of Bozeman. The vegetation goal for this project is to establish permanent, native plant species along the Bozeman Creek corridor that are appropriate for a broad range of hydrologic fluctuations.

The proposed topography of the project will create a variety of bank slopes and elevations relative to the water table, requiring a planting plan that incorporates these factors into species selection and placement. The stream channel and inset floodplain have been divided into three vegetative zones, including: transition, saturated, and emergent. Design Sheets 6 and 7 illustrate the extent of each planting zone, while Design Sheet 8 illustrates the spatial extent of each zone in cross section.

The Transition Zone (Zone 1) includes areas that extend from the drier uplands at the top of the resloped inset floodplain on the east side of the channel down to the boundary of the flat, inset floodplain. On the west side of the channel, this zone extends from the top of the tall bank down to the bankfull elevation. This zone will include a mix of upland grasses, forbs, trees and shrubs, which will be planted in dense clusters to enhance and protect the stream channel. A dense barrier of thorny shrubs such as woods rose or hawthorne will be planted in areas where public access to the channel and private lands is discouraged. Additional woody species suitable for this zone include cottonwood, aspen, willows, red-osier dogwood, serviceberry, and currant. Trees and shrubs should be installed at a density of approximately 900 plants/acre. Shrub and tree density in Zone 1 should be much greater than in Zone 2 to account for heavily planted areas where stream access will be discouraged. Herbaceous vegetation appropriate for this zone includes western wheatgrass, Idaho fescue, fowl bluegrass, and slender wheatgrass, field mint, and penstemon. The grass and forb seed mix should be hand seeded and applied at a rate of approximately 30 lbs/acre.

The Saturated Zone (Zone 2) includes the relatively flat, inset floodplain, and is characterized by semi-saturated soils that can be seasonally inundated. These areas will be revegetated with grasses and clusters of shrubs normally found in a fluctuating water regime that can be inundated for short periods of time (1 to 3 months). Appropriate woody species for this zone include red-osier dogwood, willows, and alder. Planting shrubs and trees in a clustered array will improve aesthetics by eliminating evenly spaced rows and plant spacing. Trees and shrubs should be installed at a density of approximately 770 plants/acre. Herbaceous species appropriate in this zone include torrey's rush, beaked sedge, Nebraska sedge, wooly sedge, three-square bulrush, and three stamen rush. This area will be planted with 10-cubic centimeter herbaceous tubelings of riparian species at a density of 10,890 plants/acre, or approximately 2-foot centers.

The Emergent Zone (Zone 3) includes the three foot margin immediately adjacent to the stream edge that can tolerate submersion to three feet deep for a limited period of time. Plants in this community include native wetland and riparian rushes, sedges and grasses including beaked sedge, small fruited bulrush, hardstem bulrush, three-square bulrush, and alkali bulrush, streambank wheatgrass, and tufted hairgrass. The wetland seed mix should be hand seeded at a rate of approximately 30 lbs/acre. This zone should also be planted with 10-cubic centimeter tubelings of herbaceous wetland species at a density of 10,890 plants/acre, or approximately 2-foot centers.

Specific design criteria for the revegetation of the creek's corridor include:

1. All vegetation zones will be revegetated with native riparian trees, shrubs, forbs and grass species
2. Zone 1 (upland transition zone) will be revegetated a native upland plant species, including a mix of shrubs, trees, grasses and forbs characteristic of upland transition communities along Bozeman Creek.
3. Zone 2 (saturated zone) will be vegetated with native upland/wetland seed, shrubs, and trees characteristic of the riparian communities along Bozeman Creek.

4. Zone 3 (emergent zone) will be vegetated with a native wetland seed and wetland plants characteristic of emergent communities along Bozeman Creek.

Additional Park Design Elements

Stream Accessibility

The majority of banks along the existing channel are steep and tall, creating an uninviting scenario and potentially dangerous conditions during high flows. The restoration of Bozeman Creek affords the opportunity for increased access and interaction with the stream. To encourage the use of this natural resource, a designated “public access” area will be developed in close proximity to the playground and pavilion facilities. Having one access area close to established facilities will allow for better supervision by adults and will focus the use to one small area of the restored stream. A plan view map illustrating the proposed stream access area is included on Design Sheet 9.

The access point is designed to attract people by placing sandstone blocks (2'x2'x4' TYP.), frontier stair treads (3'x2'x6" TYP.) and flagstone (2" Min Thickness). The material will be installed to resist erosion up to a 25 year flood and blend with native vegetation. The access area features a dual stair case and larger “beach” area that extends onto an inside meander point bar of the stream. The design will allow users to descend to the stream via stairs or the stone block, creating a sense of adventure for kids accessing the stream. The entrance to the stream access will be subtle and designed in tandem with the revegetation plan to encourage entrance to the stream in the designated access area. The stone and vegetation should blend seamlessly and create a sense of discovery when arriving at the access point entrance. Two benches will be located at the top of the access point to allow for adult supervision of children at play.

Specific design criteria for the access areas include:

1. Materials used to construct the access point will be installed at grade with the resloped banks of the inset floodplain
2. Materials used to construct the access point will be sized to withstand a 25-year flood event.
3. Stream access areas will direct users to the inside of a meander bend and avoid providing access to the outside of a meander bend.

Paths / Circulation

Current pedestrian access is characterized by multiple surface types. A concrete sidewalk along the south and east borders of the park connect users to Church Ave. Another small section of concrete connects the parking lot to the “tot lot” play area. The improvements to pedestrian circulation will take in to account the existing Bogert Park Master Plan. The addition of stream access points and the reconfiguration of the playground require a reconsideration of current circulation patterns. Proposed trail alterations to accommodate park users are illustrated on Design Sheet 2 and include a multi-use trail that extends from Story Street to the Bogert parking lot, a pedestrian trail spur that extends from the multi-use trail near the playground to the pavilion, and extending the sidewalk west of the footbridge.

The new circulation plan is designed to slow people down and to encourage some separation of bikers and pedestrians near the playground and pavilion. Bikers and more swiftly moving pedestrians are directed to the east of the playground and pointed towards the parking lot. Pedestrians will have a dedicated, signed trail on the west side of the playground. The location of the trail steers pedestrians to the stream access area and playground. The path will also act as a visual buffer between the stream and larger public spaces. New paths will be composed of crushed fines as a first phase of development and can be upgraded to concrete or paved surfaces in a future phase if desired.

Another alteration to the trail system is proposed where the new footbridge enters the park from the west. The new bridge span points southeast into the park recognizing that many pedestrians use the bridge as a link to Pete's Hill. The new trail will intersect with the bridge and allow pedestrians the choice to travel north towards major park amenities or south towards Pete's Hill and E. Story Street.

Specific design criteria for the new trail system include:

1. The multi-use trail will be designed for two-directional traffic and will be a minimum of 10' wide.
2. The multi-use trail will be designed for cyclist speeds of 10-15 mph and pedestrian speeds of 2-3 mph.
3. The pedestrian trail will be designed for two-directional pedestrian traffic and will be a minimum of 8' wide.
4. The pedestrian trail will be designed for speeds 2-3 mph.

Playground

The current playground is a very well used public amenity. The goal of this component is not to significantly change the playground but to recognize that there is a better way to organize the space. The stream channel realignment will require the removal of the existing swing set and code requires that a new swing set replace it. The proposed design plan moves the new swing set directly east of the tot lot. The proposed playground area allows space for six swings at a 9' height. Design Sheet 9 illustrates the proposed layout of playground features and relocated swings.

The proposed playground plan includes new seating, paths and features to complement existing playground structures. The arrangement would encourage more interaction with parents and guardians and discourage a direct line of access to the stream. The mulched area of the playground is expanded southwest to increase the area for active recreation. A series of stepping pods creates an interactive edge to the playground. The multiuse path includes a pullout at the southeast corner of the playground with two benches. Line of sight is maintained from the band shell lawn so that concert goers can still observe the playground. Existing playground equipment would be left in place with only the edge of the playground being cleaned up for better definition.

Specific design criteria for the playground design include:

1. Playground amenities will be designed with lines of sight to the stream channel and band shell to allow for improved adult supervision.

Signage

One of the most important aspects of this project is public education. The improvement and enhancement of Bozeman Creek provides native habitat for fish and wildlife, improves water quality and invites the public to experience nature first hand.

To further the public education goal signage will be used. A master display will be located near the stream access area adjacent to the playground. Before and after photos, diagrams and some educational verbiage will educate people on the process of stream restoration and the importance of healthy streams in the greater ecosystem. Additional smaller signs will point out plant names, indicate directions to adjacent amenities, inform what birds to watch for and describe the life cycles of the species of fish and plants that make Bozeman Creek and Bogert Park home. No specific design criteria are proposed for signage.

Bridge

The existing bridge crossing site will change dramatically with the new creek enhancements, creating an opportunity for a new unique, appropriate and code compliant bridge structure. The proposed bridge alignment is shown in detail on Design Sheet 10, while typical views of the bridge are illustrated on Design Sheet 11.

The west bank of the existing bridge is in the 60’ wide East Koch Street right of way, and is at the end of a semi-improved (asphalt millings, no curb, no sidewalk) dead-end street. Currently the bridge alignment starts near the north edge of the right of way with an approach from the west that passes under communication and power line pole guy wires. An electrical panel and meter array, related to a Northwestern Energy gas main cathodic protection rectifier, is present near the center of the right of way. Improving the western approach to this significant neighborhood and park pedestrian connection should be considered with the project. Extending the sidewalk by 130’ on the south side of East Koch to the bridge is included in the preliminary plan and costs for this project. The City of Bozeman may choose to complete the street section (full paving and sidewalks, curb & gutter) at a later date. Moving utilities may not be necessary and will be dependent on the final bridge alignment. Relocation of any utilities and improving the Koch street section approaching the bridge is not part of the project plan or budget.

The initial concept for a new bridge is one that creates an aperture “eddy” aligned with the watercourse below for viewing, pausing, and experiencing Bozeman Creek as well as views beyond. The alignment crosses perpendicular to the new meander and the eddy would focus down river at the playground, pavilion lawn and the Bridger Mountain backdrop. The eddy is asymmetrical on the bridge, with a shallow bench on one side and a deep standing-only area on the other. This will frame views and place the focus on the creek experience. Construction materials would include round and rectangular steel members for strength and weather resistance with an aesthetic nod to the historic log band shell nearby. Composite decking would be used for the walking surface. Bar grating in the eddy area would allow views straight down to the water. Concrete foundation embankments will be built at both ends and will be protected from stream scour with rock armor. The intersection with the east bank park trail allows for circulation to the playground and central park amenities as well as to the south and towards the Main Street to the mountains trails and Pete's Hill area. This intersection lies just north of an existing well cap and electric panel, which will remain undisturbed.

Specific design criteria for the footbridge include:

1. The new footbridge must provide sufficient freeboard to clear the 100-year water surface elevation by at least 24"
2. The bridge width will allow for two-directional traffic
3. The bridge will have a 2 ton weight capacity
4. The bridge will be designed to allow pedestrian and bike traffic, but will encourage bikers to slow down by reducing the entry width.

Utilities

The enhancement plan will require relocating a power pole and overhead power line that extends across Bozeman Creek just southwest of the pavilion. The power pole on the east side of the channel will be relocated away from the new meander bend. All other power related facilities will remain in place. Design Sheet 12 illustrates all proposed utility relocations and areas of disturbance associated with all components of the proposed project.

Specific design criteria for utilities include:

1. Minimize the extent and cost of relocating the power line to the extent possible but without compromising channel and inset floodplain design criteria.

Irrigation Line

A 2" irrigation line currently extends along the east bank of Bozeman Creek and will be rerouted along the new channel alignment. This irrigation line will be installed at its current depth (approximately 2') and further east than the stone revetment installed to prohibit lateral erosion to the east. Design Sheet 12 illustrates the proposed location for the new irrigation line along the west bank.

Specific design criteria for the irrigation line include:

1. The new line will be placed to approximately the same depth as the existing line.
2. Irrigation capacity will meet or exceed the capacity required for the park's irrigation requirements, including newly installed vegetation.

Construction Dewatering, Storm water and Erosion Control

The proposed project entails a significant amount of earthwork within and adjacent to an active stream channel. Therefore, special consideration will be given to prevent potential erosion, storm water, and excessive turbidity as a result of construction. Best Management Practices outlined in the "Montana DEQ Stormwater Management During Construction Field Guide for Best Management Practices" will be utilized in as a guideline for erosion control during construction. It is anticipated that the following categories of BMPs will be applicable to this project and will be addressed in detail during the final design phase of the project:

1. Perimeter Control and Barriers (Silt Fence, Straw Wattles, etc.)
2. Vehicle Track Pads
3. Material Handling, Equipment Management (Equipment management, spill prevention and response)
4. Waste Management (Refuse and Trash, Portable Toilets)

In addition to these BMPs, construction dewatering may include installing temporary coffer dams or pumps to divert water away from areas under construction. These efforts will provide a means of ensuring protection of water quality during the project.

Permitting

Several regulatory permits will be necessary to acquire prior to constructing the proposed project. Permitting requirements for the proposed project include:

U.S. Army Corps of Engineers 404 permit (Nationwide 27)
Gallatin Conservation District 310 permit
City of Bozeman Floodplain permit
DEQ 318 permit for temporary increase in turbidity
DEQ SWPPP permit for storm water and erosion control

The hydrologic and hydraulic analysis for the original flood insurance study (FIS) was performed by the NRCS and was completed in June 1979. A proposed re-study of Bozeman Creek may occur in the near future and may revise the predicted extent of the 100-year flood. The timing of this project with the proposed re-study will determine the need to prepare a Conditional Letter of Map Revision (CLOMR) as a result of the project's intent to revise the extent of areas inundated by a 100-year flood. If required, the CLOMR will necessitate extensive hydraulic modeling in addition to that already conducted for preliminary design purposes to satisfy FEMA requirements. At this point it is unclear as to whether the flood study and CLOMR application are required, and as such, this additional design and permitting task has not been included in the final project budget.

Project Costs

Estimated costs for final design, permitting, and all phases of construction are included in the following table. These estimated costs are based on preliminary planning for this project and should not be considered final. A 20% contingency has been added to the estimated costs to account for unknown project elements and fluctuations in material and fuel costs. The estimated cost table below is referred to as Option 1, and includes construction of all tasks in one calendar year.

Task 1 – Channel and Floodplain Construction

Description	Qty	Unit	Unit Price	Cost
Excavate new channel and floodplain alignment	3500	CY	$ 5.00	$ 17,500
Install cobbles on new point bars	300	CY	$ 25.00	$ 7,500
Install topsoil on new point bars	300	CY	$ 35.00	$ 10,500
Bioengineered bank stabilization on west bank	140	FT	$ 100.00	$ 14,000
Install stone revetment along east bank	450	FT	$ 45.00	$ 20,250
Install coir encapsulated soils lifts along outside banks	400	FT	$ 40.00	$ 16,000
Pool and riffle shaping	400	FT	$ 6.00	$ 2,400
Construction dewatering and erosion control	1	LS	$ 15,000.00	$ 15,000
Construction Oversight	120	HR	$90	$ 10,800
			Task Subtotal:	**$ 113,950**

Task 2 – Utilities and Irrigation

Description	Qty	Unit	Unit Price	Cost
Irrigation main, valve, and drain relocation	700	LF	$ 40.00	$ 28,000
Connect to existing irrigation system	3	EA	$ 500.00	$ 1,500
Repair and reconnect irrigation laterals	1	LS	$ 1,500.00	$ 1,500
Remove and reset existing power pole	1	EA	$ 3,000.00	$ 3,000
			Task Subtotal:	**$ 34,000**

Task 3 – Playground Trails, Access

Description	Qty	Unit	Unit Price	Cost
Playground				
Swingset	1	EA	$ 2,000	$ 2,000
Benches	4	EA	$ 1,100	$ 4,400
Directional Signage	2	EA	$ 250	$ 500
Educational Sign Display	1	EA	$ 1,000	$ 1,000
Playground edging	165	LF	$ 7	$ 1,155
			Subtotal:	**$ 9,055**
Trails and paths				
10' wide paths, crushed fines	425	LF	$ 12	$ 5,100
8' wide paths, crushed fines	280	LF	$ 10	$ 2,800
6' wide sidewalk	130	LF	$ 6	$ 780
			Subtotal:	**$ 8,680**
Access Areas				
Frontier Step Treads	16	EA	$ 350	$ 5,600
Frontier Stone Blocks	40	EA	$ 350	$ 14,000
Sanset Flagstone	26	EA	$ 25	$ 650
			Subtotal:	**$ 20,250**
Labor and Materials				
Earthwork allowance	1	LS	$ 5,500	$ 5,500
General Labor allowance	1	LS	$ 5,000	$ 5,000
Topsoil	100	CY	$ 35	$ 3,500
Mulch	25	CY	$ 35	$ 875
Irrigation allowance	1	LS	$ 15,000	$ 15,000
			Subtotal:	**$ 29,875**
			Task Subtotal:	**$ 67,860**

Task 5 - Revegetation

Description	Qty	Unit	Unit Price	Cost
5 gallon shrubs - installed	245	EA	$ 50	$ 12,250
10-T plant plugs - installed	2800	EA	$ 6	$ 16,800
1.5" cal. trees - installed	84	EA	$ 400	$ 33,600
1 gallon perennials - installed	100	EA	$ 14	$ 1,400
Seeding	16200	SQ FT	$ 1	$ 12,150
			Task Subtotal:	**$ 76,200**

Task 5 – Bridge

Description	Qty	Unit	Unit Price	Cost
Install bridge with "eddy" feature for viewing	1	EA	$ 140,000	$ 140,000
			Task Subtotal:	**$ 140,000**

Task 6 - Final Design and Permitting

Description	Qty	Unit	Unit Price	Cost
Final Design				
Refine hydrology	1	LS	$ 4,000	$ 4,000
Hydraulics and sediment transport analyses	1	LS	$ 6,000	$ 6,000
Final channel and floodplain design drawings and specs	1	LS	$ 15,000	$ 15,000
Final playground, trails, access and revegetation design	1	LS	$ 10,500	$ 10,500
Final utility and irrigation design	1	LS	$ 3,500	$ 3,500
Final structural and bridge aesthetics design	1	LS	$ 12,800	$ 12,800
Prepare final design report	1	LS	$ 10,000	$ 10,000
Prepare monitoring plan	1	LS	$ 3,000	$ 3,000
Prepare bid package	1	LS	$ 1,700	$ 1,700
Project metings with City, BCEC	1	LS	$ 3,500	$ 3,500
			Subtotal:	**$ 70,000**
Permitting				
Prepare and submit joint regulatory permits	1	LS	$ 4,000	$ 4,000
Prepare and submit SWPPP permit	1	LS	$ 2,000	$ 2,000
Permitting fees - (floodplain, 318, SWPPP)	1	LS	$ 1,000	$ 1,000
			Subtotal:	**$ 7,000**
			Task Subtotal:	**$ 77,000**

Total Cost of Project (Tasks 1 - 6):	**$ 509,010**
20% Contingency	**$ 101,802**
Total Cost + Contingency	**$ 610,812**

Project Phasing

If funding limitations prevent constructing the entire project in one phase (Option 1), there are two options proposed for splitting the project into two phases. It should be noted that extending the timeframe of the project will likely increase expenditures due to multiple equipment mobilizations and additional project management fees necessary for a lengthier project.

Option 2 – Construct one meander at a time

Phase 1 Tasks		**Cost**
Final design and permitting	$	77,000
Install bank toe along west bank	$	14,000
Construct upper meander and floodplain	$	39,850
Revegetation	$	38,100
Install bridge	$	140,000
Phase 1 Total	**$**	**308,950**
20% Contingency	**$**	**61,790**
Subtotal	**$**	**370,740**
Phase 2 Tasks		**Cost**
Construct lower meander and floodplain	$	39,850
Construct cobble revetment	$	20,250
Revegetation	$	38,100
Install access area	$	20,250
Relocate utilities and irrigation	$	34,000
Modify park playground and trails	$	47,610
Phase 2 Total	**$**	**200,060**
20% Contingency	**$**	**40,012**
Subtotal	**$**	**240,072**
Phase 1 & 2 Total	**$**	**509,010**
20% Contingency	**$**	**101,802**
Subtotal	**$**	**610,812**

Option 3 – Construct stream channel first followed by playground and trails

Phase 1 Tasks		**Cost**
Final design and permitting	$	77,000
Construct upper meander and floodplain	$	39,850
Install bank toe along west bank	$	14,000
Construct lower meander and floodplain	$	39,850
Construct cobble revetment	$	20,250
Revegetation	$	76,200
Relocate utilities and irrigation	$	34,000
Total	**$**	**301,150**
20% Contingency	**$**	**60,230**
Subtotal	**$**	**361,380**
Phase 2 Tasks		**Cost**
Install bridge	$	140,000
Install access area	$	20,250
Modify park playground and trails	$	47,610
Total	**$**	**207,860**
20% Contingency	**$**	**41,572**
Subtotal	**$**	**249,432**
Phase 1 & 2 Total	**$**	**509,010**
20% Contingency	**$**	**101,802**
Subtotal	**$**	**610,812**

Implications for Final Design

Hydrology

It is important to note that the hydrology analyses performed do not provide substantial input as to what the geomorphically relevant bankfull discharge should be at the project site. Final design efforts should consider additional analyses including:

- Measuring discharge during a bankfull event (if one occurs) at reference locations where floodplain connectivity is unaffected by channel alterations. A proper reference reach for Bozeman Creek at Bogert Park is not available due to urbanization and channel modifications in the vicinity of the project. A more appropriate location to measure bankfull discharges would include in Bozeman Creek and Matthew Bird Creek upstream of the project site where natural floodplain characteristics exist. The bankfull discharge would be the sum of the estimated bankfull discharges at the two sites.
- The estimated bankfull discharge should take into account the Story Ditch diversion structure, which is immediately upstream of Bogert Park. Any water diverted at this structure should be quantified to determine the effects it has on the discharge through Bogert Park.
- Survey bankfull channel dimensions at several riffles and a longitudinal profile within a reference channel segment in Bozeman Creek and Matthew Bird Creek. Develop an estimate of bankfull discharge using at-a-station hydraulics to estimate the discharge at the bankfull elevation.

If funding is available, it would be advantageous to install a continuous flow monitoring device in Bozeman Creek to more accurately estimate the range of flows throughout the year. Base flows should be more accurately determined by measuring the stream discharge in Bogert Park on multiple days between January and March. Following the determination of base flows, this discharge should be incorporated into the final design by:

- Ensuring channel dimensions are adequate to provide fish passage during base flows.
- Ensuring residual pool depths are adequate for fish during base flows.

Channel Alignment

- The final channel alignment will allow for a determination of all necessary mature tree removal. All trees necessary for removal should be specified in the final design.

Channel Dimensions

The most important factor in developing final channel dimensions for pool and riffle features is the determination of a bankfull discharge (see final design components for hydrology). The final bankfull discharge should be used as a hydraulic modeling and sediment transport input to develop the final suite of channel cross section dimensions.

- Channel dimensions proposed in this preliminary design report should be verified and refined during final design by integrating hydraulic models with basic sediment transport analyses to derive channel dimensions that account for the influence of the proposed new pedestrian bridge, convey the established bankfull discharge, provide for overbank flow above the bankfull discharge, and result in neither degradation nor aggradation of the channel bed.

Lateral Stability and Bank Treatments

- Final design elements should include a hydraulic analysis at meander bends to determine the shear stress along the channel banks.
- Stone toe and gravel bank gradations should be designed using incipient motion calculations to withstand the shear exerted on the banks up to the discharges specified in the design criteria.
- Coir fabric lifts should be designed to withstand the anticipated shear exerted on the top 1' of the banks.
- Vegetative components of the soil lifts such as willow stakes and placement of wetland sod mats within the coir should be incorporated into the final design specifications.

Vertical Stability and Stream Bed Composition

- Final design elements should include an analysis of sediment transport and incipient motion to design riffle and pool bed materials that will only mobilize at the discharges specified in the design criteria.

100-year Floodplain through Bogert Park

- The final design will require a grading plan that meets the specified design criteria. Once a grading plan is finalized, a hydraulic model of proposed conditions will be necessary to determine the elevation of a 100-year flood event using regional regression equations. This elevation will determine the approximate extent of flooding through the park and provide the necessary documentation for obtaining a City floodplain permit.

Inset Floodplain Development

- The final design will need to consider the extent of footers on the west side of the pavilion and the buffer distance away from those footers necessary to maintain structural stability.
- Once this buffer is defined, the extent of the inset floodplain adjacent to the pavilion can be finalized.
- The final design should document where the existing, mature vegetation will prevent excavation of the inset floodplain adjacent to the pavilion. The preliminary plan specifies a 5:1 slope that extends from the inset floodplain elevation up to meet the existing elevations to the east and west side of the channel; however, this slope may be modified in specific areas to reduce mature tree removal.

Vegetation

- Final design elements for the revegetation component of the project should include developing a final list of native species in each planting zone and developing a specific planting plan for each zone. The final planting plan will specify native seed mixes, size of plants (1 gal, 5 gal, tree caliper, etc.), cluster locations, and installation techniques.

Stream Access

- The final design should select an appropriate location for the stream access site. The access site as shown in the preliminary design plans is adjacent to a cluster of large cottonwood trees that may limit access to the channel on the inside of the meander bend. An alternative location includes the inside bend of the next meander to the south, although this location is blocked from view from the playground by a large spruce tree.
- The final design will specify stone sizes and locations for stone placement.

Paths / Circulation

- The final design for the paths should revise the preliminary plan, if necessary, to an alignment that leads park users to the final locations of the stream access area and bridge.
- The design will specify materials (gravel trails vs. concrete paths) necessary for construction of the trail and sidewalk network.
- The final design will detail the reconstruction of the sidewalk and approach to the new footbridge from the west.

Playground

- The final design should include a plan for revising the playground, including relocation and replacement of the swing set and the addition of observation benches and playground equipment.

Signage

- The final design should specify locations and construction materials for interpretive signs and describe the information conveyed on each sign.

Bridge

- The final design should include a final location, alignment, and span of the new footbridge.
- A structural engineering design should accompany the final design and provide details and specifications for the bridge and support footers.

Utilities

- The final design should include a final location for relocating the power pole on the east side of Bozeman Creek.

Irrigation

- The preliminary design offers a location for the new irrigation line; however, the final design should specify locations for irrigation valves and lines that will feed off the main irrigation line.
- The final irrigation plan will be designed in accordance with the final revegetation plan.

Final Design Report

Following completion of all final design analyses, a report will be generated that describes the analyses performed, provides results of the analyses, and offers a description of how and why the final design deviated from the preliminary design. This report will include revised drawings in 11x17" format illustrating all components of the preliminary design report.

Monitoring Plan

A monitoring plan will accompany the final design report and will provide a description of methods appropriate for monitoring public reactions, vertical and lateral channel stability, habitat complexity, bed substrate composition, geomorphology, success of revegetation, and biological responses (fish and macroinvertebrates) to the enhancement measures.

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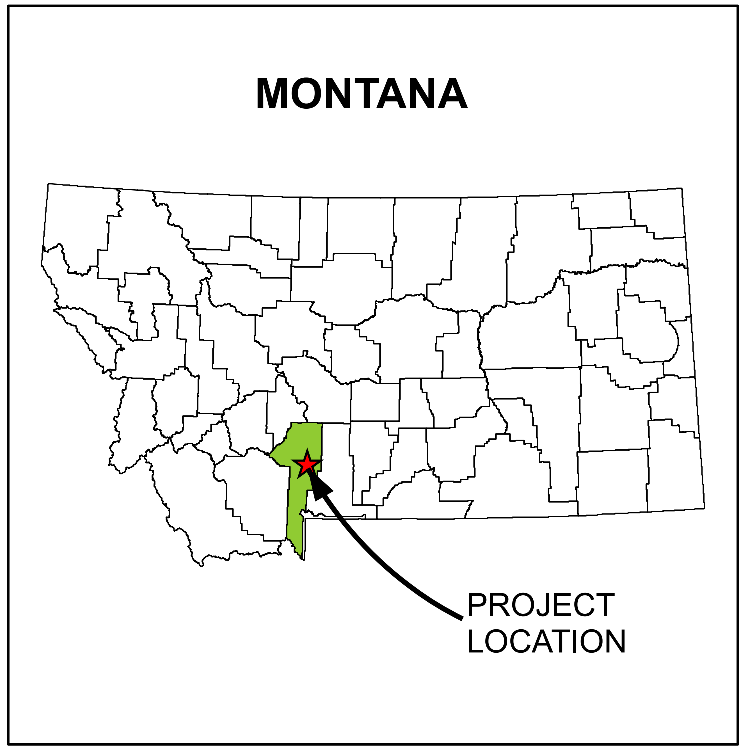

SHEET INDEX

BOZEMAN CREEK ENHANCEMENT AT BOGERT PARK PRELIMINARY DESIGN

PREPARED FOR:

City of Bozeman
City Clerk's Office
Suite 102, City Hall
121 North Rouse Avenue
Bozeman, Montana

PREPARED BY:

CONFLUENCE CONSULTING, INC
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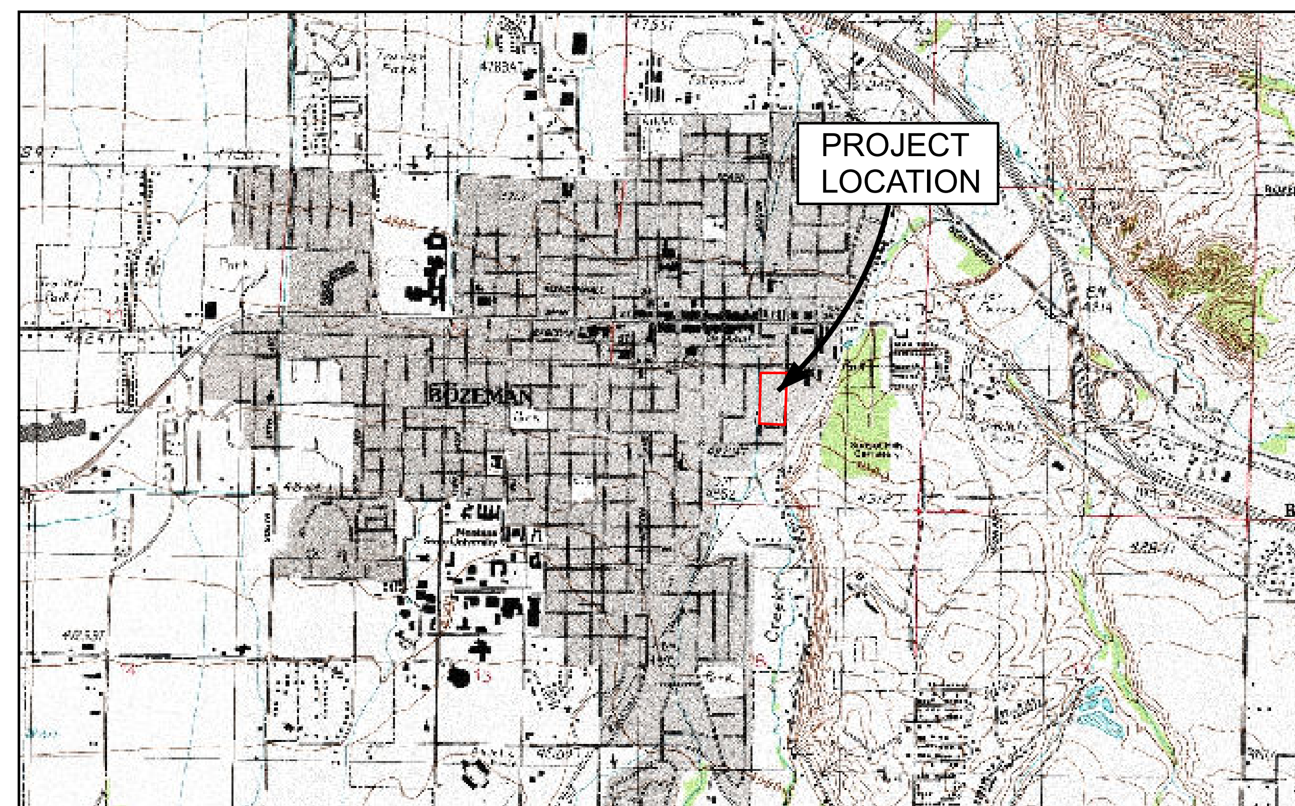
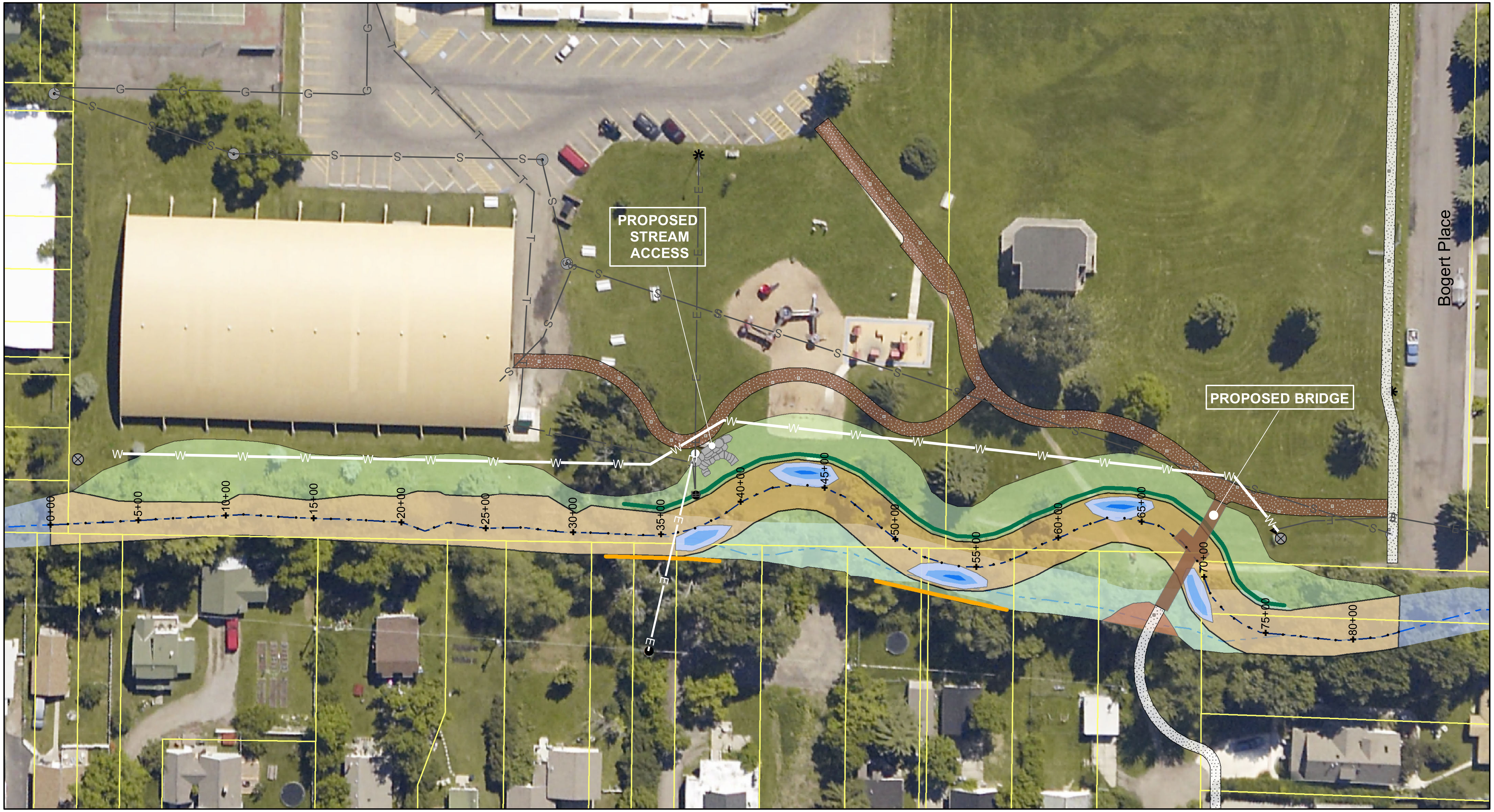
BOZEMAN, MT 59771

PROJECT VICINITY AERIAL PHOTO



PROJECT VICINITY TOPOGRAPHIC MAP



Legend

- Existing Channel
- Proposed Channel
- Proposed Inset Floodplain
- Proposed Pools
- Proposed Sidewalk
- Proposed Gravel Trail
- West Bank Rock Toe
- Floodplain Revetment
- Property Lines

Utilities

- — T — Existing Underground Telephone
- — G — Existing Underground Gas Line
- — S — Existing Sewer Line
- — E — Existing Underground Electric
- — W — New Irrigation Line
- — E — New Overhead Power Line
- Electrical Panel
- Light Pole
- Manhole
- Power Pole
- New Power Pole
- Well

0 25 50 100 Feet

NOT FOR CONSTRUCTION

DRAWN BY: R. BURNS	DATE: 07/01/2012
DESIGNED BY: M. SANCTUARY, R. BURNS	CCI JOB NO. CBOZ.001
CHECKED BY: M. SANCTUARY	FILE NAME: *sheet_planview.mxd*

REV.	DATE	DESCRIPTION	BY	APP'D

CONFLUENCE consulting incorporated

TD&H Engineering

intrinsik ARCHITECTURE INCORPORATED

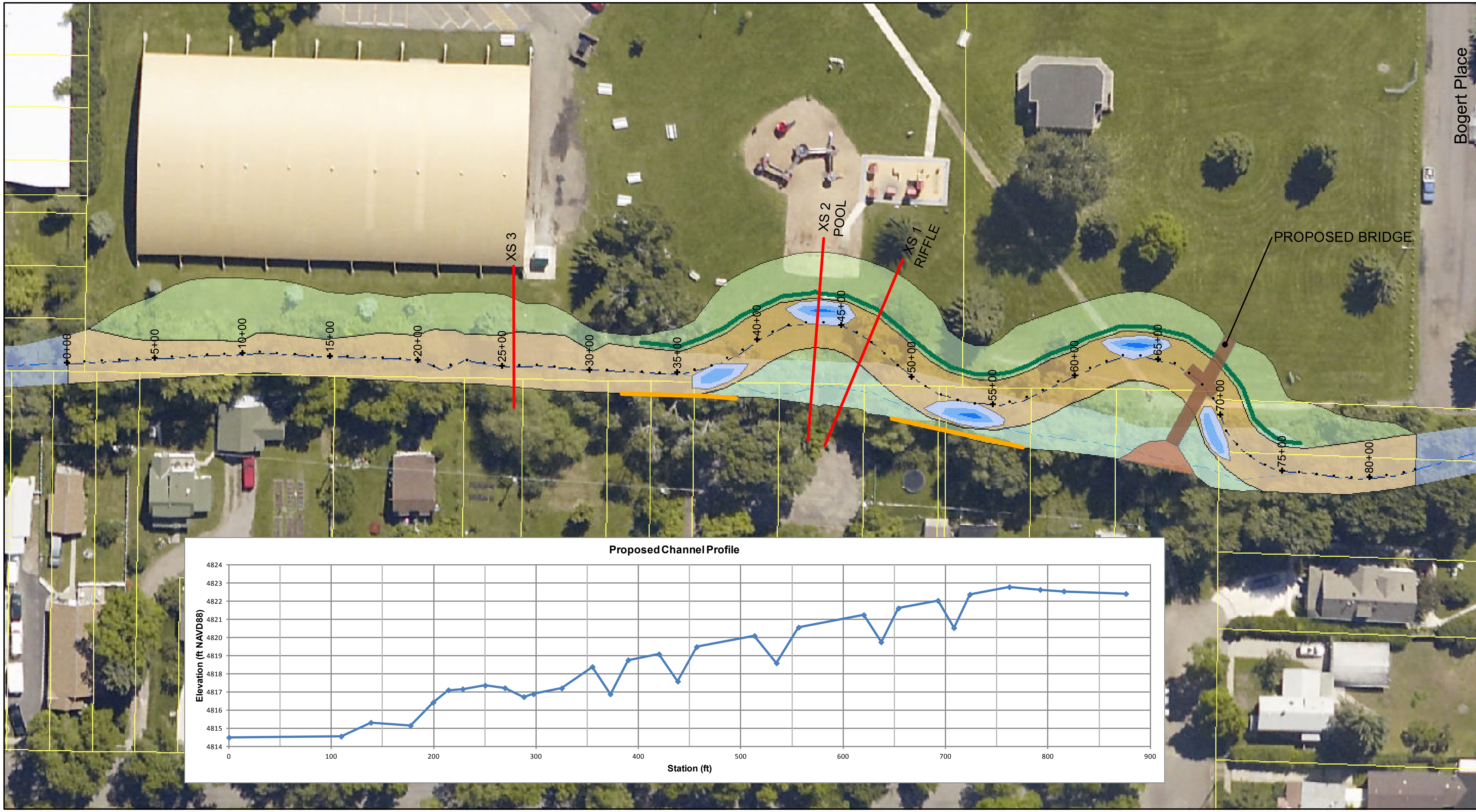
NISHKIAN MONKS

DESIGN 5

BOZEMAN CREEK ENHANCEMENT AT BOGERT PARK PRELIMINARY DESIGN

Project Overview

SHEET: 2



Legend

- Existing Channel
- Proposed Channel
- Proposed Inset Floodplain
- Proposed Pools
- West Bank Rock Toe
- Floodplain Revetment
- Design Cross Sections
- Property Lines
- Major Contour
- Minor Contour

N

0 25 50 100 Feet

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DRAWN BY: R. BURNS		DATE: 05/08/2012
DESIGNED BY: M. SANCTUARY, R. BURNS		CCI JOB NO. CBOZ.001
CHECKED BY: M. SANCTUARY	FILE NAME: *sheet_planview.mxd*	

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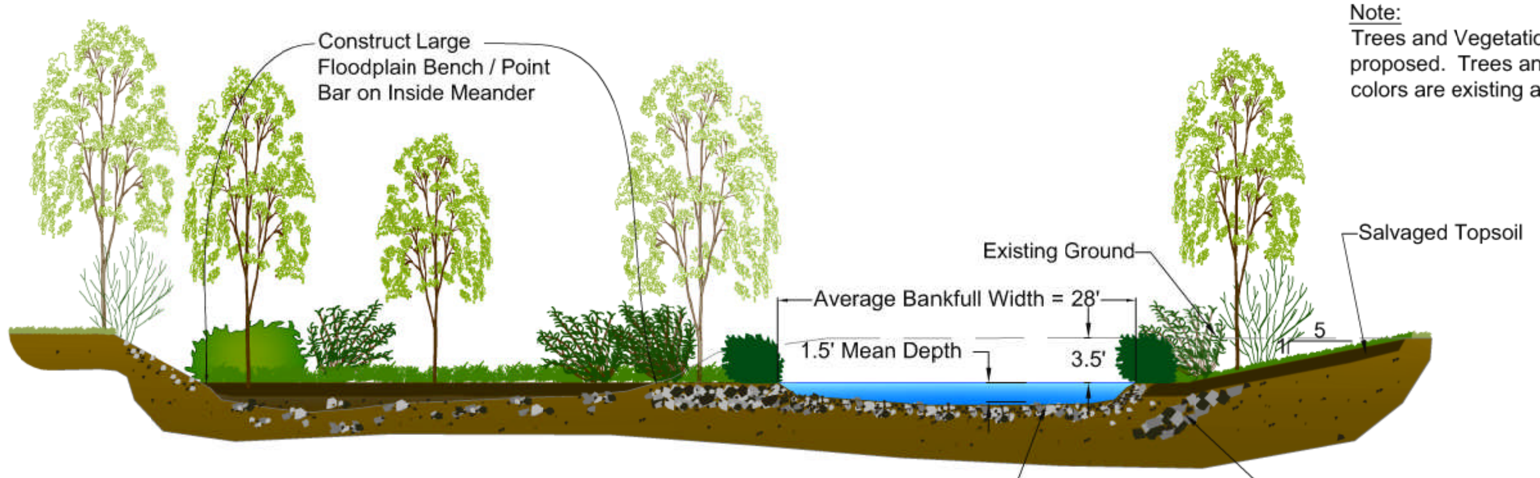
BOZEMAN CREEK ENHANCEMENT AT BOGERT PARK PRELIMINARY DESIGN

PLAN VIEW AND PROFILE

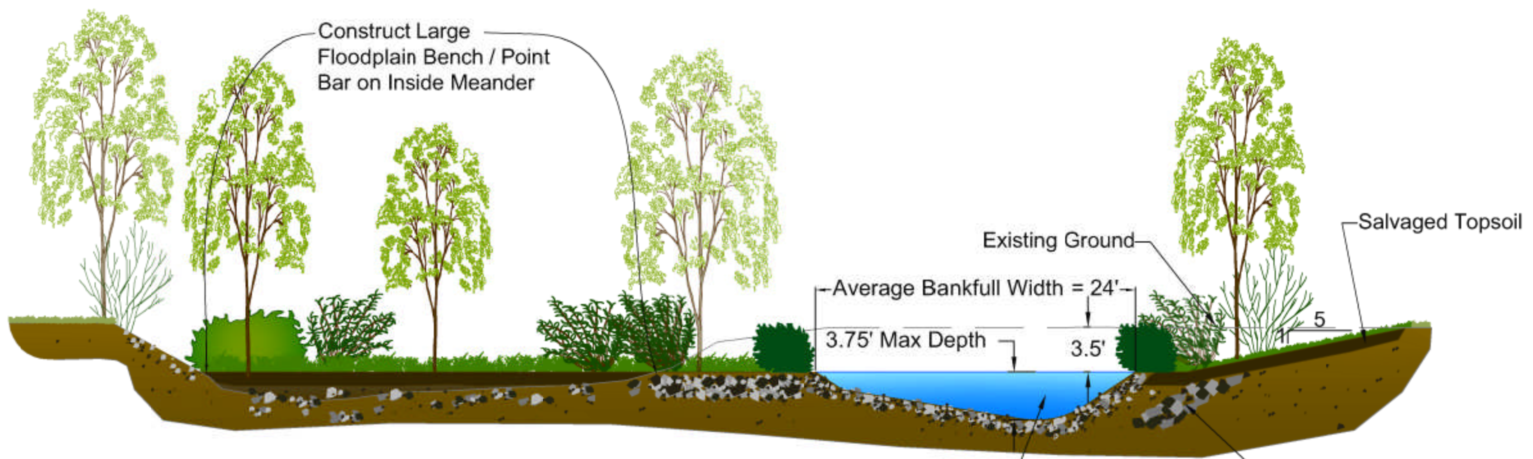
SHEET: 3

Note:
Trees and Vegetation in bold are proposed. Trees and vegetation in faded colors are existing and are to remain.

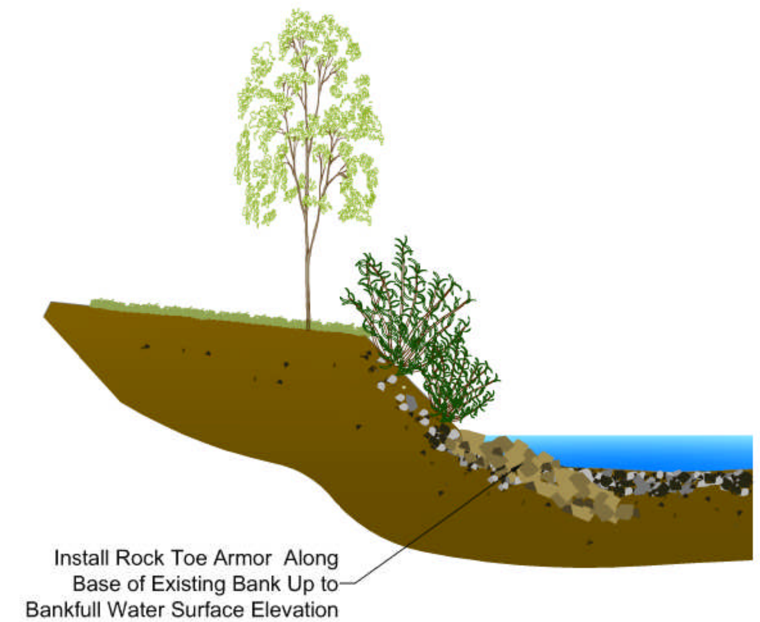
Chanel Segment	Parameter	Reach Average (ft)	Reach Minimum (ft)	Reach Maximum (ft)
Existing channel	XS Bankfull width	28.5	22	35
	XS Mean bankfull depth	1.5	1.3	1.7
	XS W/D ratio	19.5	12.5	26.6
Riffles in relocated channel segment	XS Bankfull width	28	25	31
	XS Mean bankfull depth	1.5	1.4	1.6
	XS Max bankfull depth	1.75	1.6	1.9
	XS W/D ratio	19	15.2	21.6
Pools in relocated channel segment	XS Bankfull width	25	23	27
	XS Mean bankfull depth	2.1	2.0	2.2
	XS Max bankfull depth	3.2	3.1	3.5
	XS W/D ratio	12.1	13.3	10.7



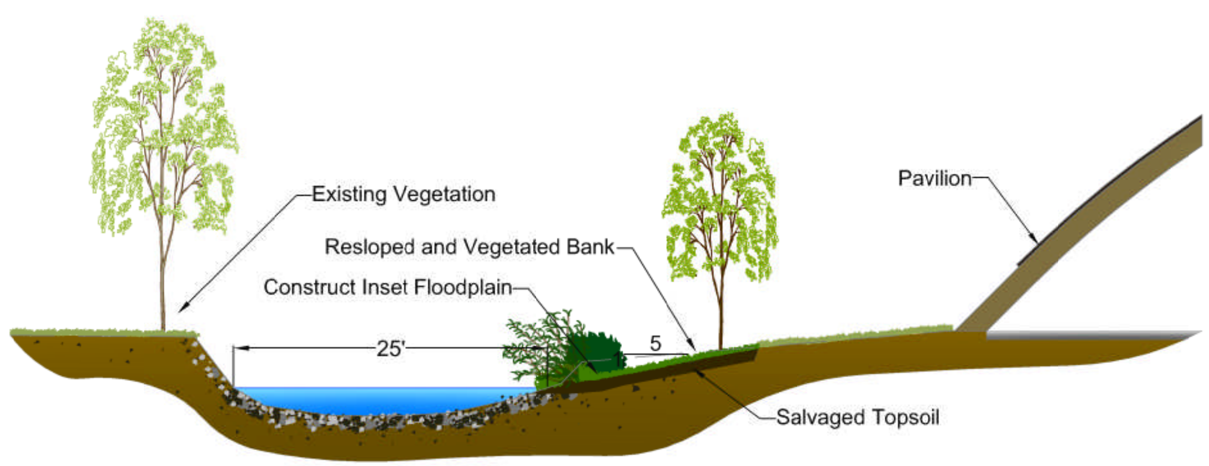
CROSS SECTION 1 - TYPICAL RIFFLE CROSS SECTION FOR NEW MEANDERS
Scale - 1":15'



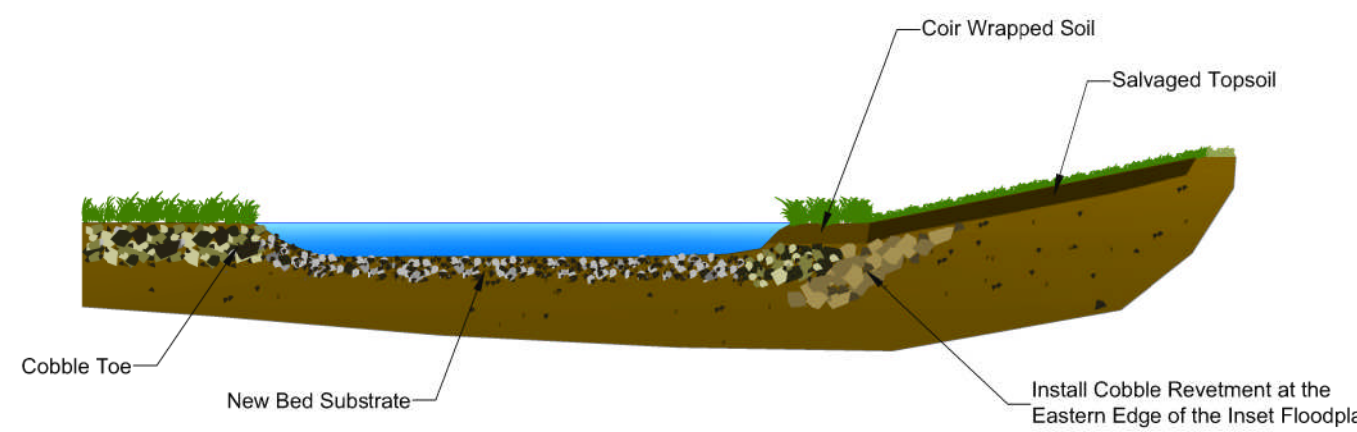
CROSS SECTION 2 - TYPICAL POOL CROSS SECTION FOR NEW MEANDERS
Scale - 1":15'



WEST BANK ROCK TOE (TYPICAL)
Scale - 1":10'



CROSS SECTION 3 - TYPICAL CROSS SECTION ADJACENT TO PAVILION
Scale - 1":15'



RELOCATED CHANNEL CONSTRUCTION (TYPICAL)
Scale - 1":10'

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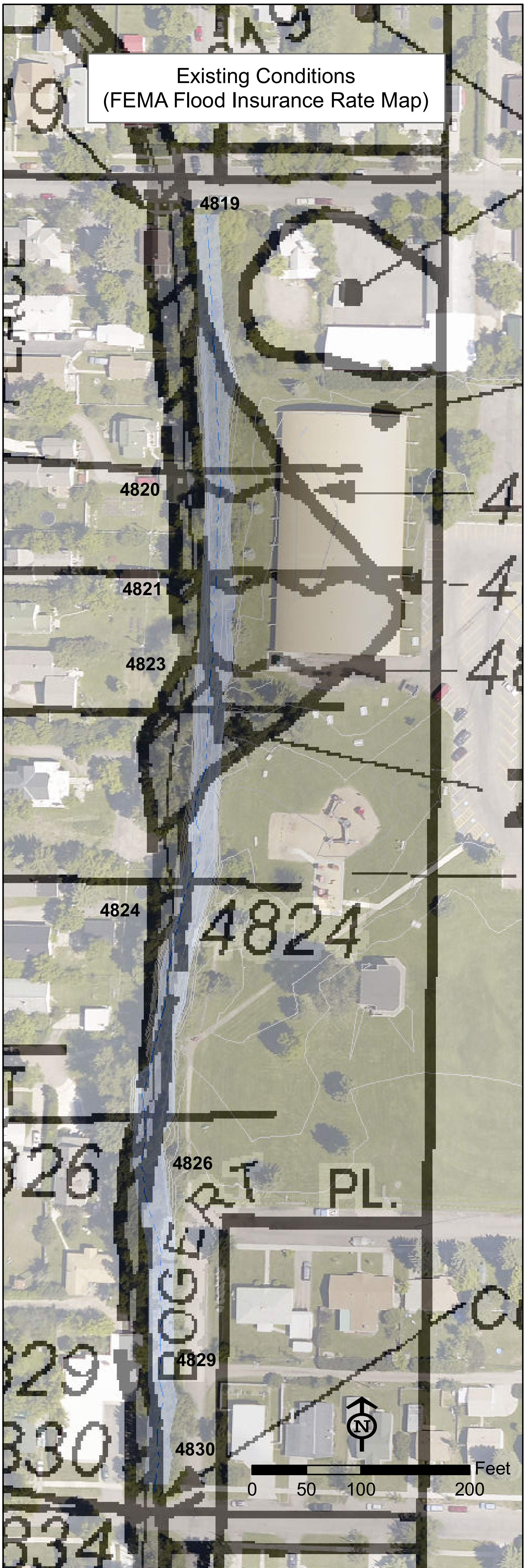
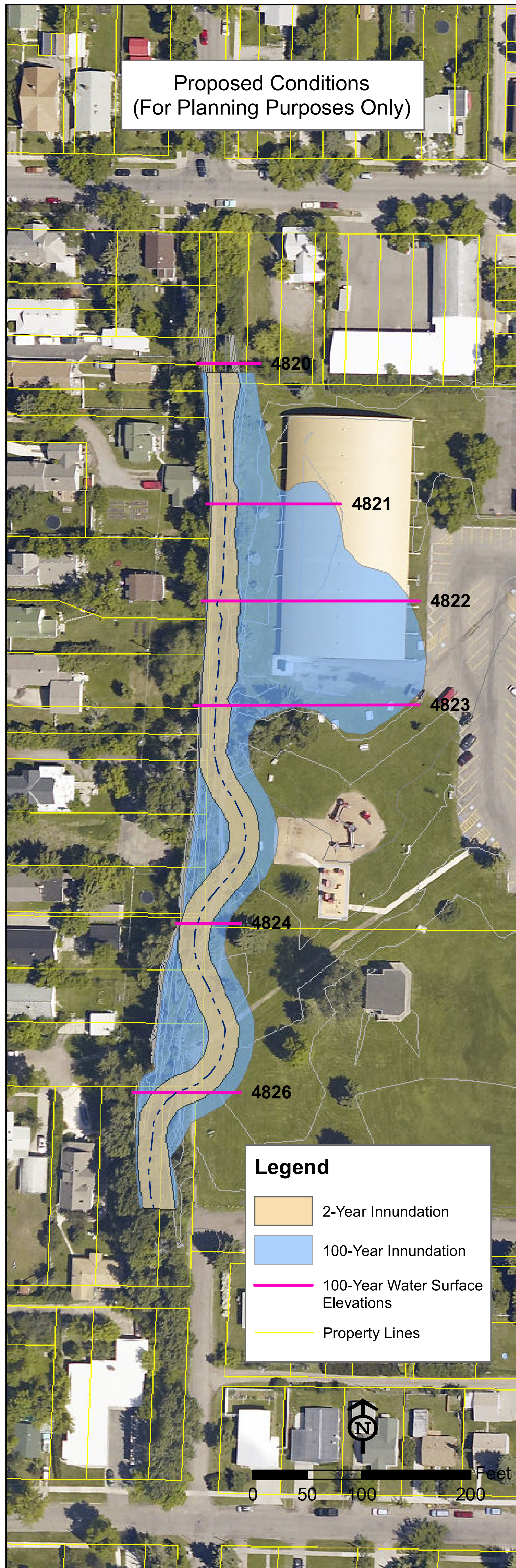
BOZEMAN CREEK ENHANCEMENT AT BOGERT PARK PRELIMINARY DESIGN

TYPICAL CROSS SECTIONS AND DETAILS

SHEET: 4





BOZEMAN CREEK ENHANCEMENT AT BOGERT PARK PRELIMINARY DESIGN

EFFECTIVE AND PROPOSED 100-YEAR FLOODPLAIN

SHEET: 5

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DESIGN 5

DRAWN BY: R. BURNS	DATE: 05/08/2012
DESIGNED BY: M. SANCTUARY, R. BURNS	CCI JOB NO. CBOZ.001
CHECKED BY: M. SANCTUARY	FILE NAME: Sheet_floodmap.mxd

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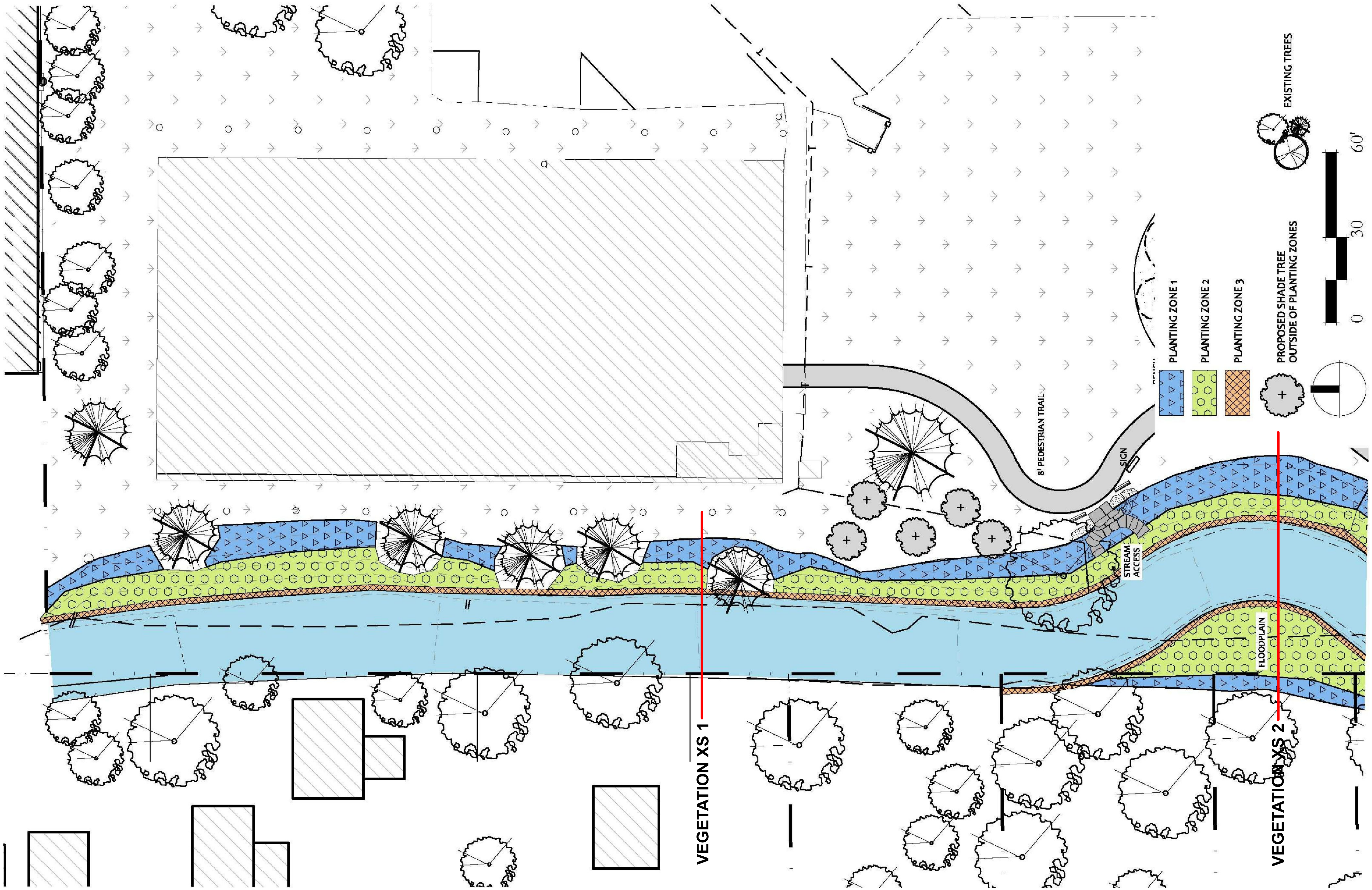

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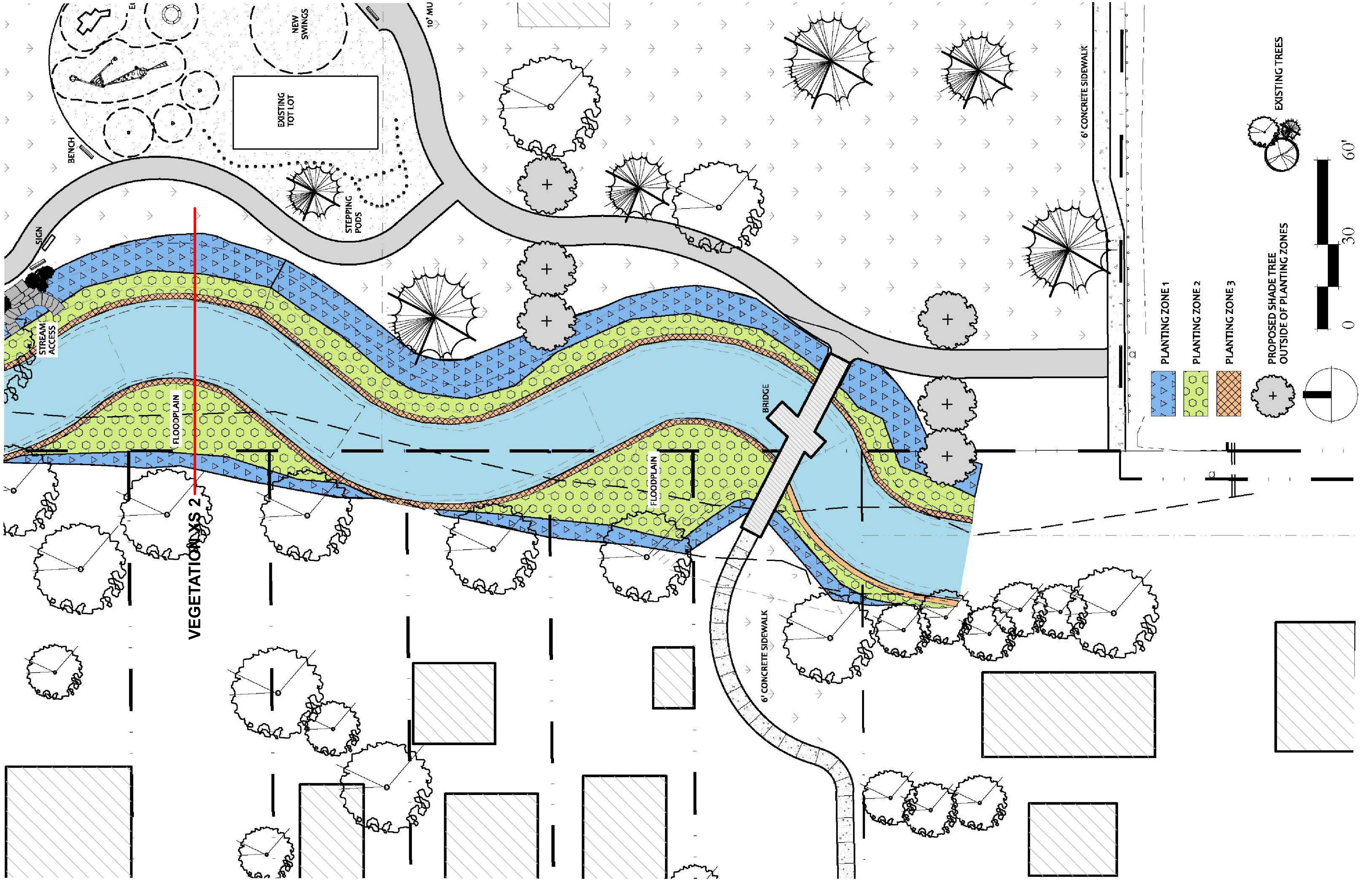
DESIGN 5

BOZEMAN CREEK ENHANCEMENT AT BOGERT PARK PRELIMINARY DESIGN

PLANTING ZONES NORTH

SHEET: 6



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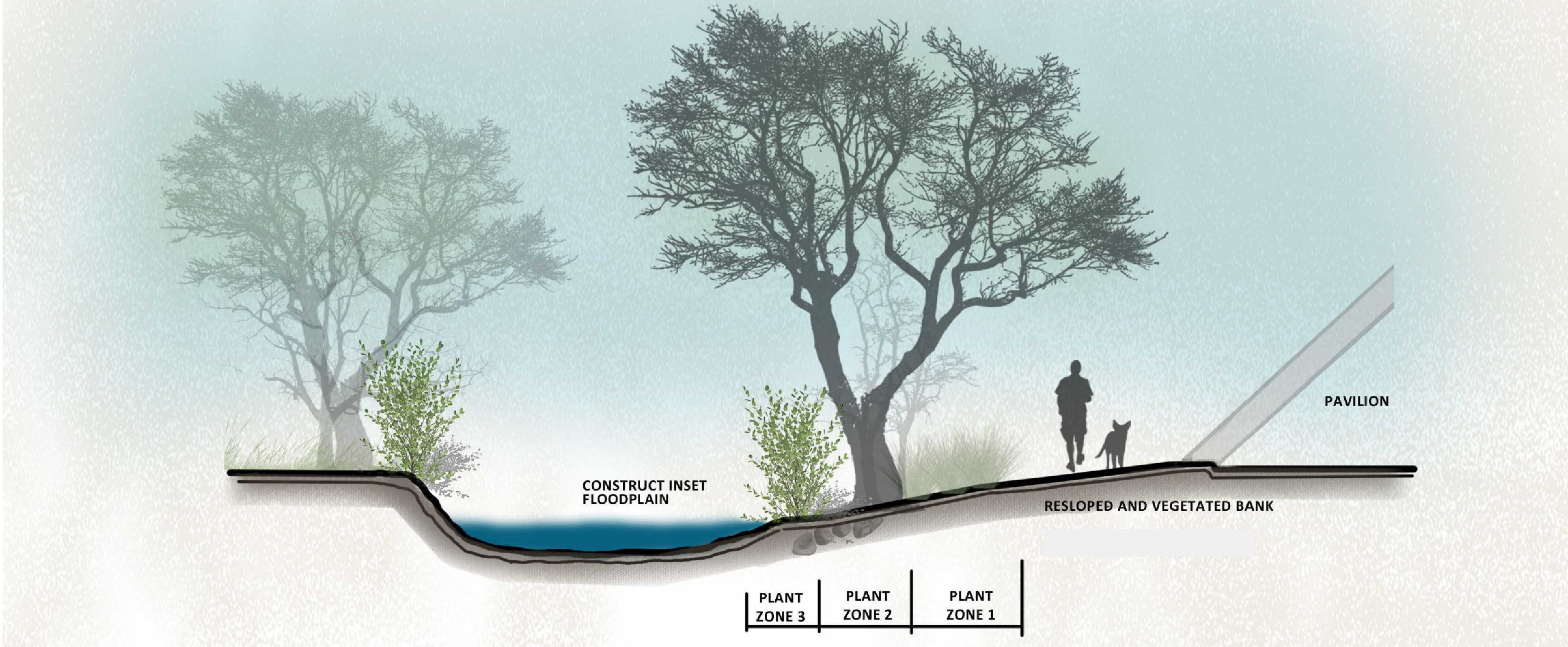
REV	DATE	DESCRIPTION	BY	APP'D

BOZEMAN CREEK ENHANCEMENT AT BOGERT PARK PRELIMINARY DESIGN

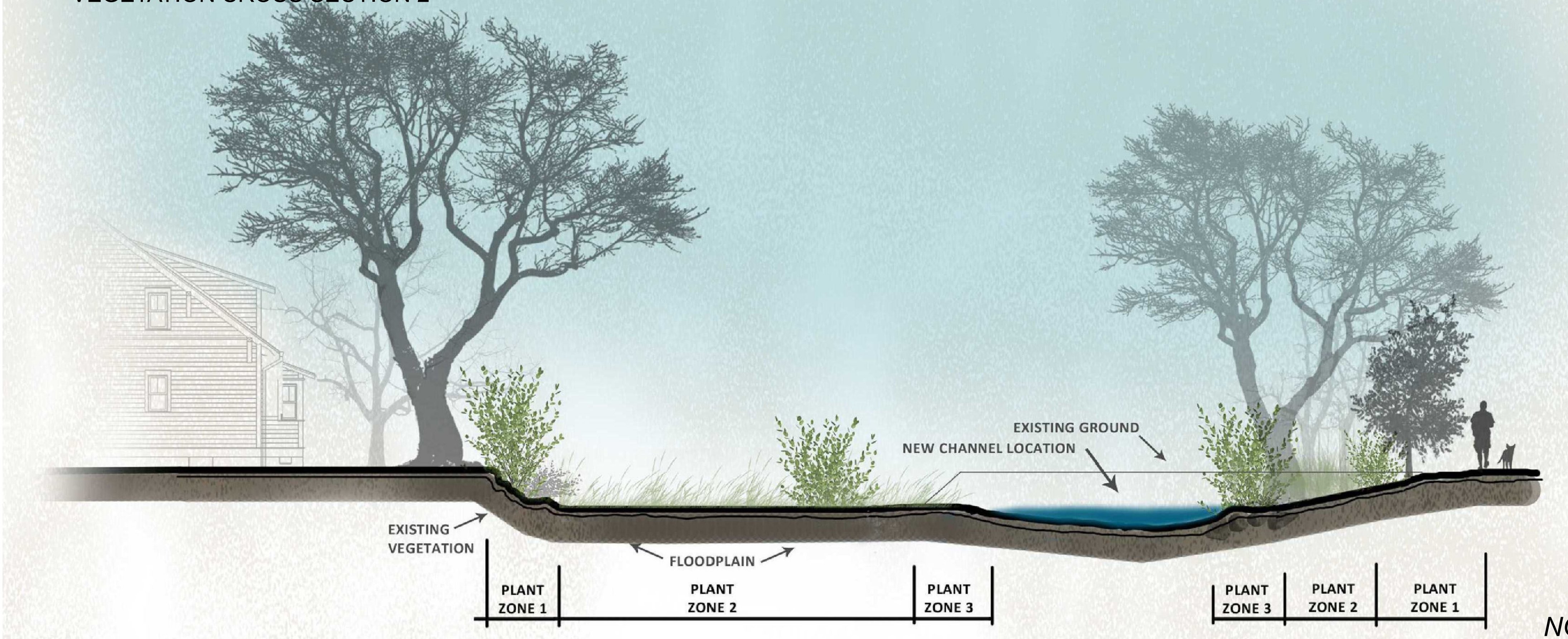
PLANTING ZONES SOUTH

SHEET: 7

VEGETATION CROSS SECTION 1



VEGETATION CROSS SECTION 2



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DESIGNED BY: DESIGN 5
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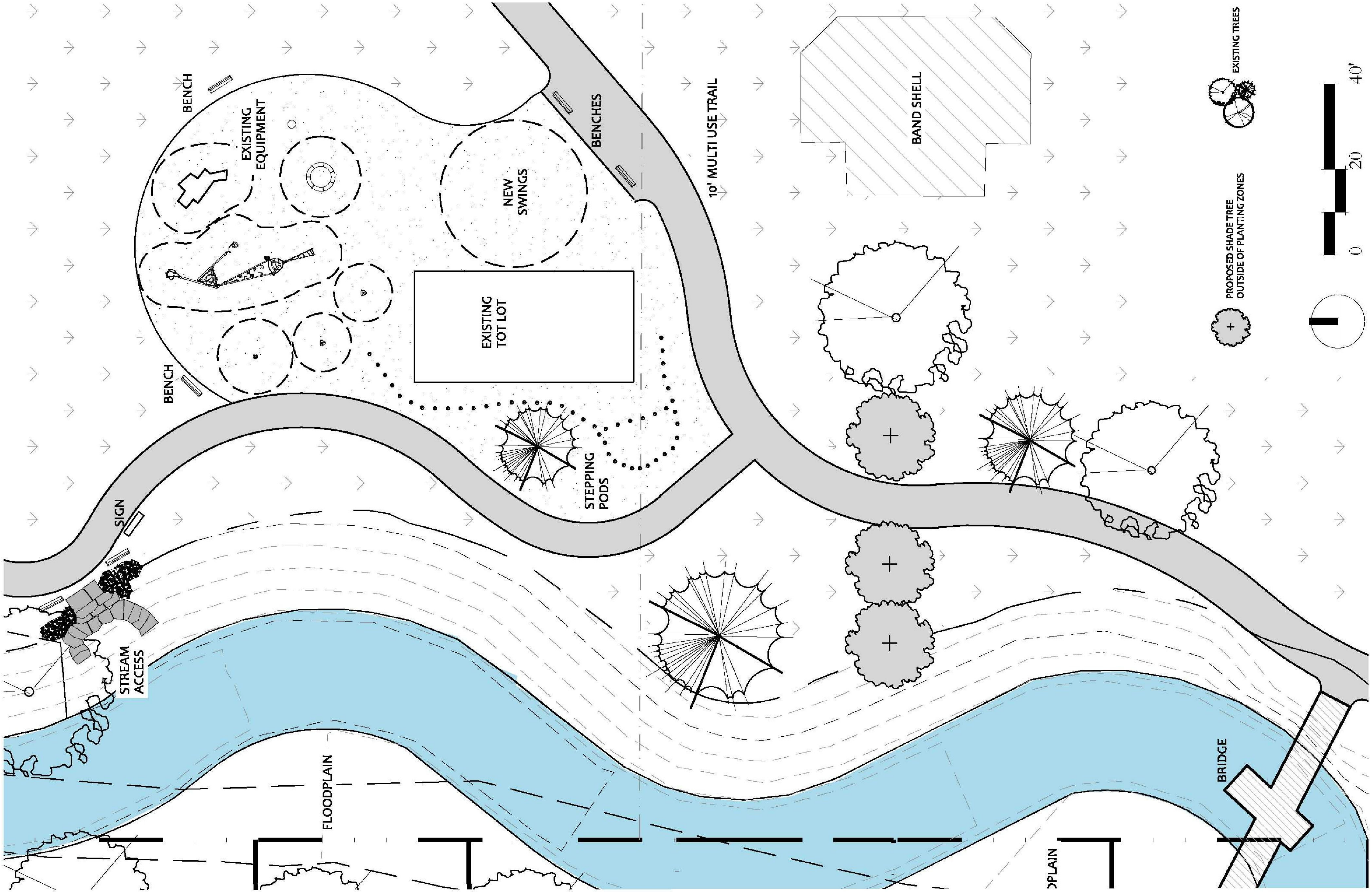
DATE: 05/10/2012
CCI JOB NO. CBOZ.001
FILE NAME: plants_xs.mxd

REV	DATE	DESCRIPTION	BY	APP'D

BOZEMAN CREEK ENHANCEMENT AT BOGERT PARK PRELIMINARY DESIGN

VEGETATION CROSS SECTIONS

SHEET: **8**



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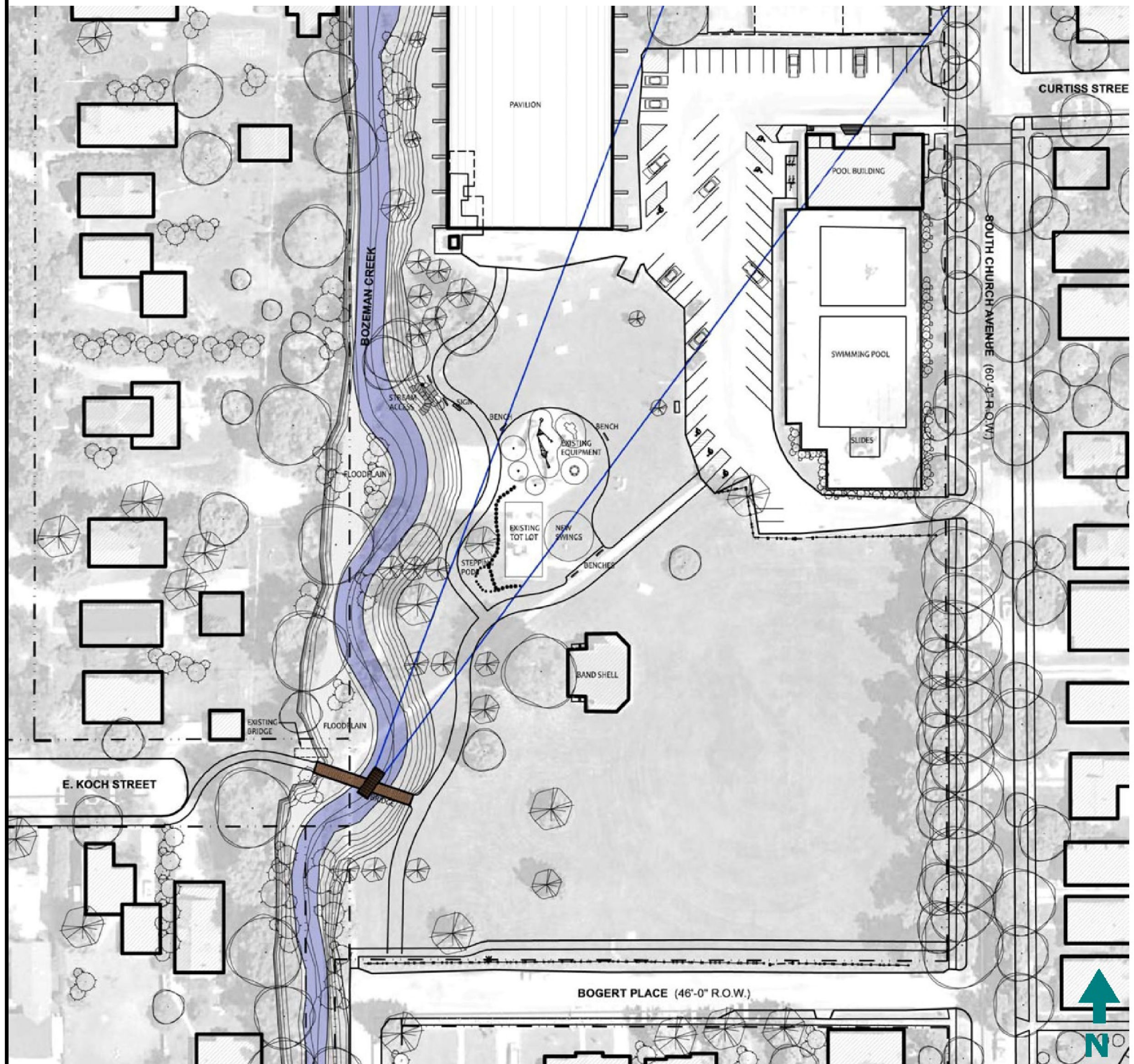
DESIGN 5

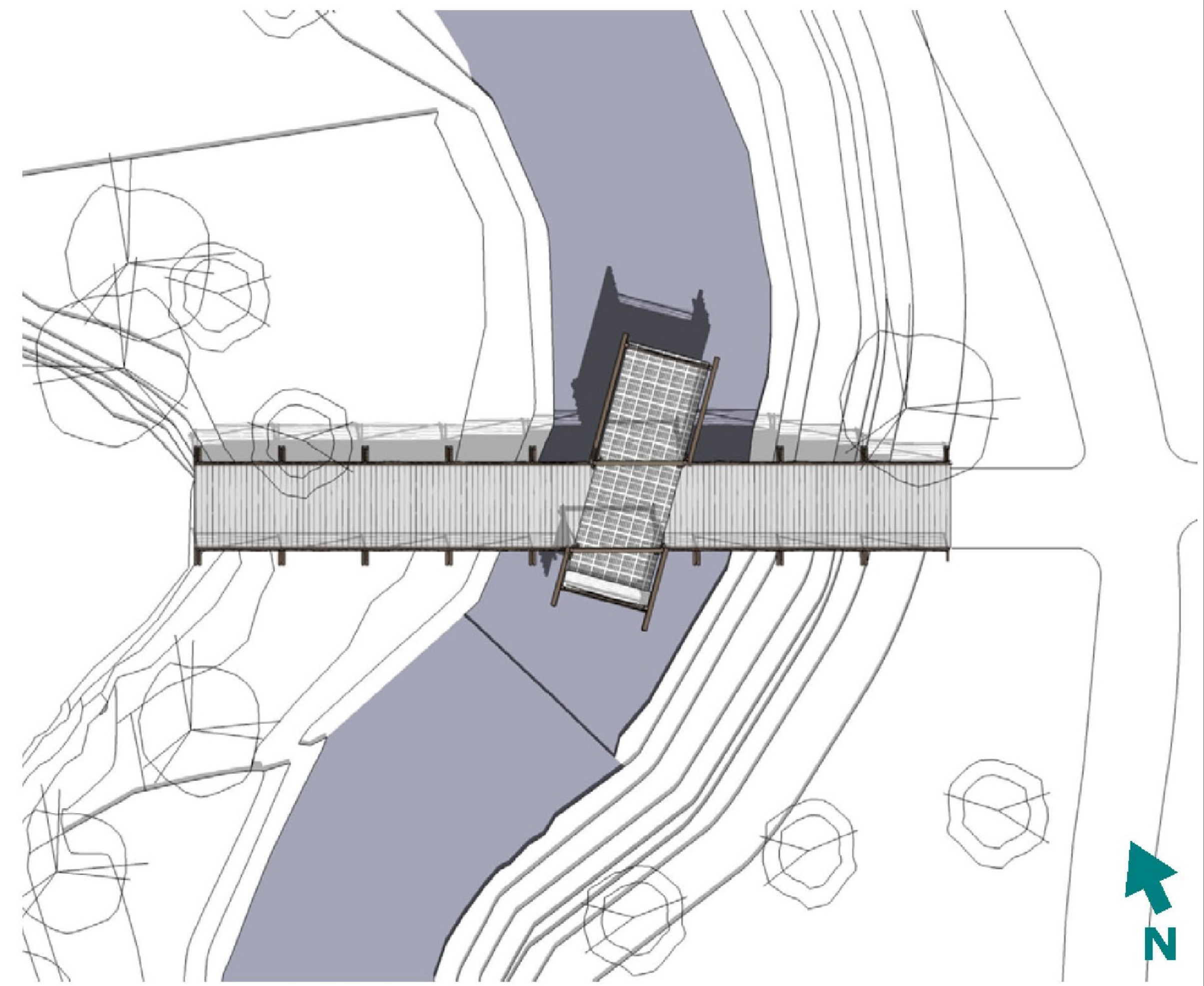
BOZEMAN CREEK ENHANCEMENT AT BOGERT PARK PRELIMINARY DESIGN

PLAYGROUND AND STREAM ACCESS DETAIL

SHEET: 9



SITE PLAN (N.T.S.)



ENLARGED SITE PLAN (N.T.S.)

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DESIGNED BY: INTRINSIK	CCI JOB NO. CBOZ.001
CHECKED BY: M. SANCTUARY	FILE NAME: *bridge_siteplan.mxd*

REV.	DATE	DESCRIPTION	BY	APP'D

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DESIGN 5

BOZEMAN CREEK ENHANCEMENT AT BOGERT PARK PRELIMINARY DESIGN

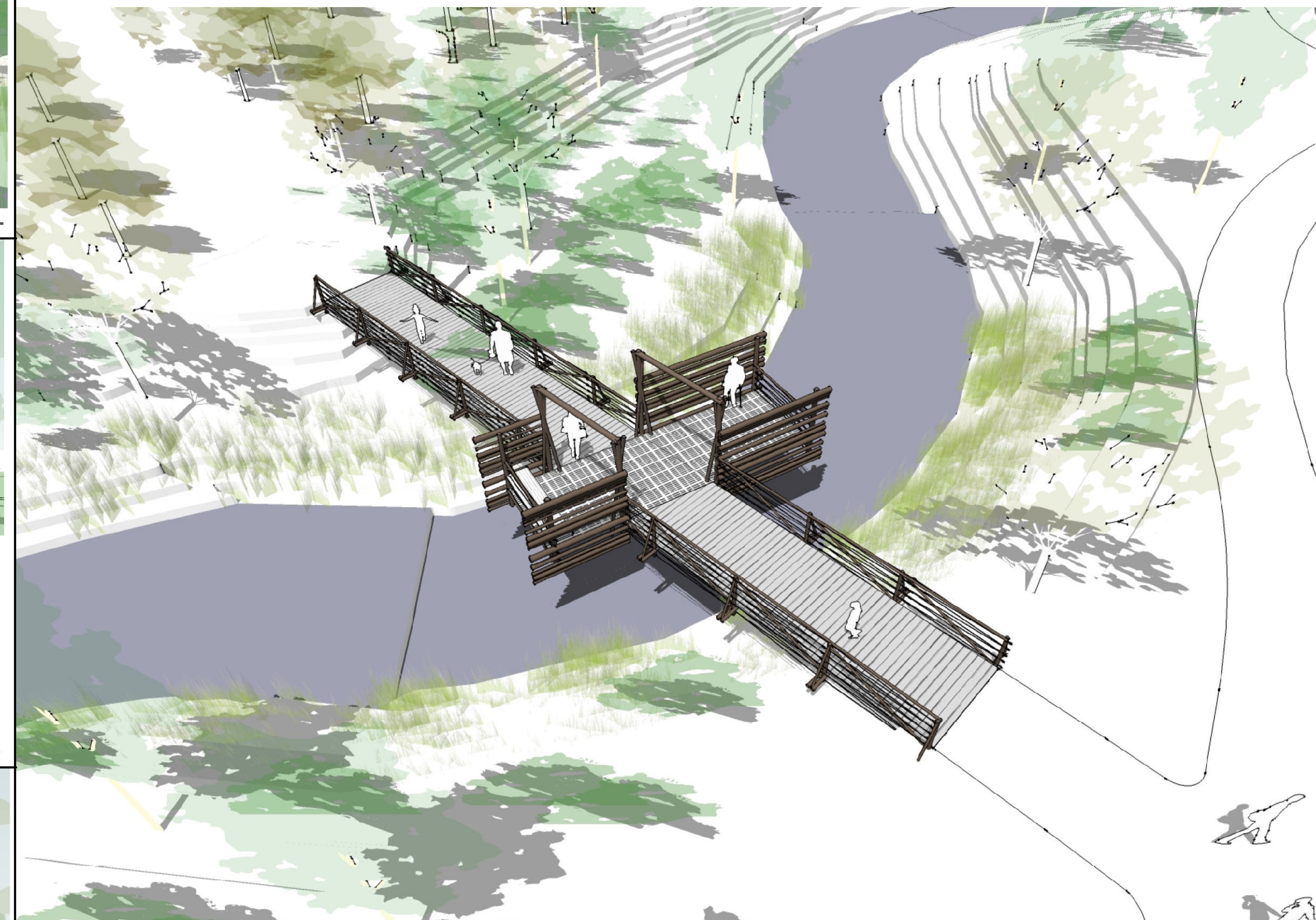
BRIDGE SITE PLAN

SHEET: **10**

RENDERING LOOKING SOUTHWEST

RENDERING LOOKING NORTH

RENDERING LOOKING WEST



RENDERING LOOKING NORTHWEST

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DESIGNED BY: INTRINSIK
CHECKED BY: M. SANCTUARY
DATE: 05/09/2012
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FILE NAME: *bridge_otherviews.mxd*

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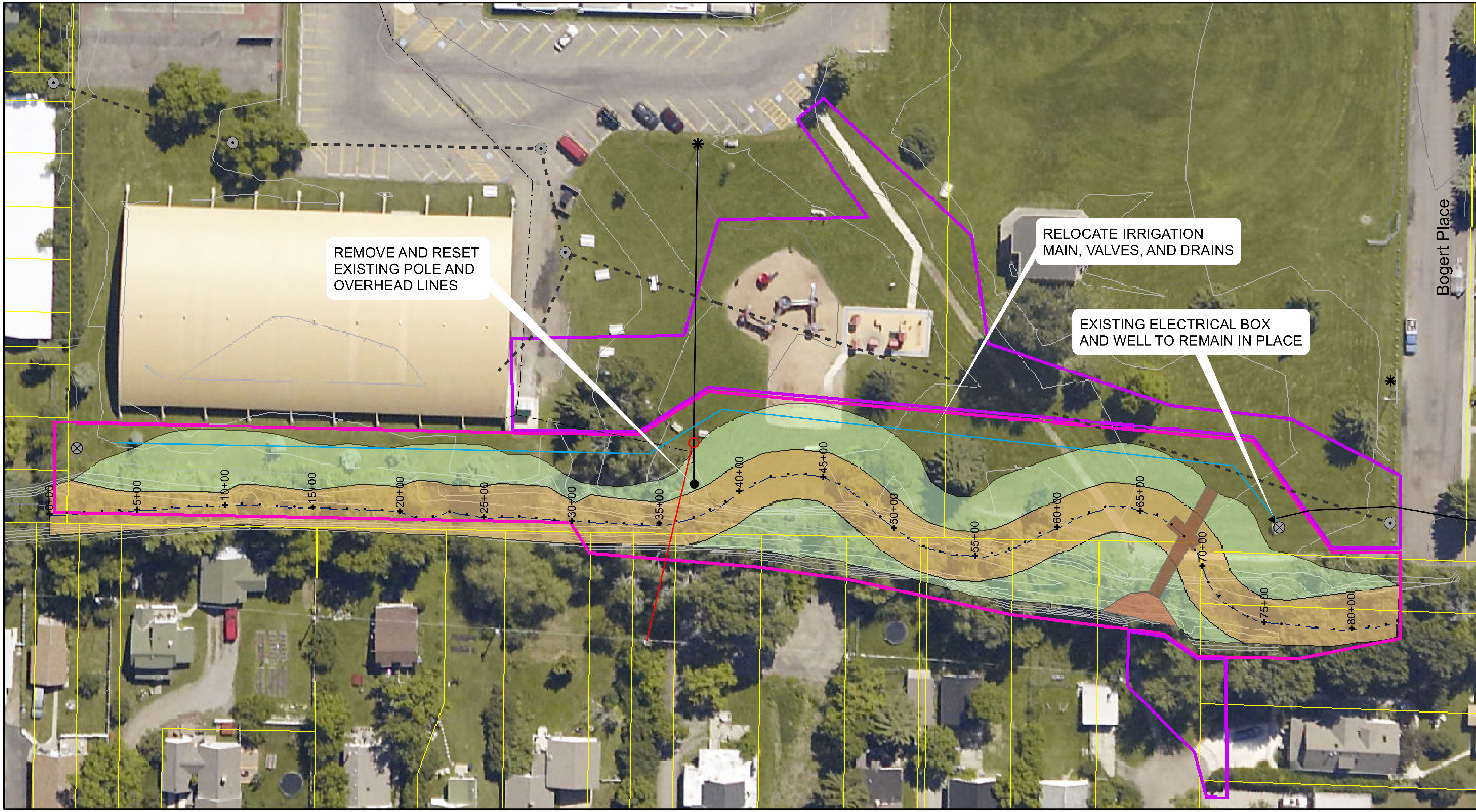
DESIGN 5

BOZEMAN CREEK ENHANCEMENT AT BOGERT PARK PRELIMINARY DESIGN

PROPOSED BRIDGE

SHEET: 11



Legend

- Proposed Channel
- Proposed Inset Floodplain
- Major Contour
- Minor Contour
- New Overhead Power Line
- New Irrigation Line
- Property Lines

Disturbance Limits

- Park Construction
- Stream Construction

Utilities

- ▲ Electrical Panel
- ✱ Light Pole
- Manhole
- ● Power Pole
- ⊗ Well
- Sewer
- Underground Gas Line
- Underground Electric
- Underground Telephone

0 25 50 100 Feet

NOT FOR CONSTRUCTION

DRAWN BY: R. BURNS	DATE: 05/08/2012
DESIGNED BY: M. SANCTUARY, R. BURNS	CCI JOB NO. CBOZ.001
CHECKED BY: M. SANCTUARY	FILE NAME: *sheet_utilities.mxd*

REV.	DATE	DESCRIPTION	BY	APP'D

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DESIGN 5

BOZEMAN CREEK ENHANCEMENT AT BOGERT PARK PRELIMINARY DESIGN

UTILITY RELOCATION AND CONSTRUCTION LIMITS

SHEET: 12